

GUIDELINES ON QUALITY SYSTEMS FOR ROAD BRIDGES

(PLAIN, REINFORCED, PRESTRESSED AND COMPOSITE CONCRETE)



INDIAN ROADS CONGRESS
1998



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MEMBERS OF THE BRIDGE SPECIFICATIONS AND STANDARDS COMMITTEE (As on 2.12.1996)

1.	A.D. Narain* (Convenor)	DG(RD) & Addl. Secretary to the Govt. of India, Ministry of Surface Transport (Roads Wing), New Delhi
2.	Chief Engineer (B) S&R (Member-Secretary)	Ministry of Surface Transport (Roads Wing), New Delhi
3.	S.S. Chakraborty	Managing Director, Consulting Engg. Services (I) Pvt. Ltd., 57, Nehru Place, New Delhi-110019
4.	Prof. D.N. Trikha	Director, Structural Engg. Res. Centre, Sector-19, Central Govt. Enclave, Kamla Nehru Nagar, PB No. 10, Ghaziabad-201002
5.	R.H. Sarma	Chief Engineer, MOST (Retd.), C-7/175, Safdarjung Dev. Area, New Delhi-110016
6.	Ninan Koshi	DG(RD) & Addl. Secy., MOST (Retd.), 56, Nalanda Apartments, Vikaspuri, New Delhi
7.	S.N. Mane	Sr. Vice President Lok Global & National Constn. Ltd., Lok Centre, Marol-Maroshi Road, Andheri (E), Mumbai-400059
8.	G. Bhatwa	Chief Engineer (NH), P.W.D., B&R Branch, Patiala
9.	A.G. Borkar	A-1, Susnehi Plot No. 22, Arun Kumar Vaidya Nagar, Bandra Reclamation, Mumbai-400050
10.	N.K. Sinha	Chief Engineer (PIC), Ministry of Surface Transport (Roads Wing), Transport Bhavan, New Delhi-110001
11.	P.B. Vijay	Director General (Works), Central Public Works Department, Nirman Bhavan, Room No.424, New Delhi-110011
12.	H.P. Jamdar	Secretary to the Govt. of Gujarat, R&B Department, Block No. 14, Sachivalaya Complex, Gandhinagar-382010
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16.	V. Murahari Reddi	Engineer-in-Chief (R&B), Errum Manzil, Hyderabad-580482
17.	M.V.B. Rao	Head, Bridge Division, Central Road Research Institute, P.O. CRRI, Delhi-Mathura Road, New Delhi-110020
18.	Prof. C.S. Surana	Civil Engg. Department, Indian Institute of Technology, Hauz Khas, New Delhi-110016
19.	C.R. Alimchandani	Chairman & Managing Director, STUP Consultants Ltd., 1004-5 & 7, Raheja Chambers, 213, Nariman Point, Mumbai-400021
20.	N.C. Saxena	Director, Intercontinental Consultants & Technocrats (P) Ltd., A-11, Green Park, New Delhi-110016

* ADG(B) being not in position. The meeting was presided by Shri A.D. Narain, DG(RD) & Addl. Secy. to the Govt. of India MOST

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22.	B.S. Dhiman	Managing Director, Span Consultants (P) Ltd., Flats 3-5, (2nd Floor), Local Shopping Centre, J-Block, Saket, New Delhi-110017
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24.	S.A. Reddi	Dy. Managing Director, Gammon India Ltd., Gammon House, Veer Savarkar Marg, Prabhadevi, Mumbai-400025
25.	Dr. G.P. Saha	Chief Engineer, Hindustan Construction Co. Ltd., Hinson House, Lal Bahadur Shastri Marg, Vikhroli (West), Mumbai-400083
26.	P.Y. Manjure	Principal Executive Director, The Freyssinet Prestressed Concrete Co. Ltd., 6/B, 6th Floor, Sterling Centre, Dr. Annie Besant Road, Worli, Mumbai
27.	Papa Reddy	Managing Director Mysore Structural Ltd., 12, Palace Road, Bangalore-560052
28.	Vijay Kumar	General Manager UP State Bridge Corpn. Ltd., 486, Hawa Singh Block, Khel Gaon, New Delhi-110049
29.	P.C. Bhasin	324, Mandakini Enclave, Greater Kailash-II, New Delhi-110019
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40.	Vinod Kumar	Director & Head (Civil Engg.), Bureau of Indian Standards, Manak Bhavan, New Delhi-110002
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42.	DG(RD) & Hon. Treasurer Indian Roads Congress	A.D. Narain - Ex-Officio
43.	Secretary, Indian Roads Congress	S.C. Sharma - Ex-Officio

Corresponding Members

1.	Shitala Sharan	Adviser Consultant, Consulting Engg. Services (I) Pvt. Ltd., 57, Nehru Place, New Delhi-110019
2.	Dr. M.G. Tamhankar	Dy. Director & Head, Bridge Engg. Division, Structural Engg. Research Centre, Ghaziabad (U.P.)

GUIDELINES ON QUALITY SYSTEMS

FOR ROAD BRIDGES

(PLAIN, REINFORCED, PRESTRESSED AND COMPOSITE CONCRETE)

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SECTION 1

INTRODUCTION

1.1. Background

The Committee for Reinforced, Prestressed and Composite Concrete Bridges (B-6) was constituted by the Indian Roads Congress to look into various aspects including improvements in the existing codes and practices. The composition of the Committee is as under :

- | | |
|---------------------|------------------|
| 1. Shri Ninan Koshi | Convenor |
| 2. Shri N.K. Sinha | Member-Secretary |

Members

- | | |
|-------------------------|--|
| 3. Shri S.G. Joglekar | 12. Dr. T.N. Subba Rao |
| 4. Shri D.T. Grover | 13. Shri Jayant Basu Roy |
| 5. Shri A.D. Narain | 14. Shri P.B. Vijay |
| 6. Shri Shitala Sharan | 15. Shri V. Murahari Reddy |
| 7. Shri M.K. Mukherjee | 16. Shri V.M. Madge |
| 8. Dr. M.G. Tamhankar | 17. Shri P.D. Gupta |
| 9. Shri Mahesh Tandon | 18. Dr. N. Rajagopalan |
| 10. Shri M.K. Bhagwagar | 19. Rep. of R.D.S.O. |
| 11. Shri S.A. Reddi | 20. Rep. of Bureau of Indian Standards |

Ex-Officio Members

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2. Hon. Treasurer, IRC (Shri A.D. Narain, Director General (Road Dev. & Addl. Secy., MOST)
3. Secretary, IRC, (Shri S.C. Sharma, Chief Engineer (Roads), MOST)

Corresponding Members

- | | |
|--------------------|------------------------|
| 1. Shri Ashok Basa | 2. Shri A. Chakrabarti |
| 3. Shri P.S. Tyagi | |

The B-6 Committee decided that a document be prepared on 'Guidelines on Quality Systems for Road Bridges' using reinforced, prestressed and composite concrete construction, keeping in view current international practice. In July, 1993 the Committee appointed a Group with the following personnel, for preparation of draft guidelines:

- | | |
|---------------------|------------------|
| Shri N.V. Merani | Convenor |
| Shri S.G. Joglekar | Member-Secretary |
| Shri A.G. Borkar | Member |
| Shri S.A. Reddi | Member |
| Shri P.Y. Manjure | Member |
| Shri Shitala Sharan | Member |

The draft guidelines prepared by the Group were discussed by B-6 Committee and were approved on 14th February 1996. These were further considered and approved by the Bridge Specifications and Standards Committee in their meeting held at New Delhi on 2.12.96. Later on, these guidelines were approved by the Executive Committee during its meeting held at New Delhi on 21.12.96 and by the Council during its meeting held at Nagpur on 13.1.97.

1.2. Need for Guidelines in Quality Systems

In order to achieve the aim of building safe, serviceable, durable and economic concrete bridges, the structural elements should meet certain requirements. The characteristics that a structure should

possess to fulfil these requirements have to be specified. The codes of practice and the contract documents strive to achieve this by way of defining design criteria, practical rules, technical specifications, testing and acceptance criteria and workmanship. All these strategies implicitly depend upon human skill for their successful and reliable application which, eventually, determines the quality of the bridge. The basic desire to produce quality work is essential in the minds of all those connected with bridge projects.

In order to achieve the required level of quality of the final product, as specified by engineering science, it is necessary to have a strategy for management of human skills by way of Quality System defining quality policy, quality assurance plan and quality audit. Apart from this, it is also necessary to explicitly define 'Quality' itself, which is expected to be achieved through the Quality System. These guidelines have, therefore, been evolved to facilitate preparation of appropriate Quality System for individual bridge projects. Use and application of these guidelines will inculcate, in all those involved in bridge building activity, an ability to provide the product or services expected of them consistently, thereby, assuring the users and instilling confidence in the users.

In drafting these guidelines, an attempt has been made to achieve compliance with the international codes of ISO 9000 series on Quality Systems, published by International Standards Organisation. Compliance with the present guidelines will be a step towards obtaining ISO Quality Certification, enabling Indian designers and contractors to compete internationally.

1.3. **Scope**

These guidelines cover quality systems for activities of bridge construction using concrete elements. These include project preparation, design and drawing, construction and supervision, contract management, quality of materials and equipment used in construction, and workmanship. The guidelines also cover the organisational requirement for adoption of quality system by suppliers, purchasers, owners, approving authorities and consultants.

These guidelines will enable :

- i) compliance with codal requirements of quality control.
- ii) setting up of internal quality systems for each of the organisations dealing with various aspects of bridge construction.
- iii) setting up of external quality systems by the supplier, to ensure conformance to specified requirements :
 - a) at final inspection or,
 - b) during production and installation, or
 - c) during several stages such as design/development, production, installation and maintenance
- iv) setting up of long term policies and procedures for quality systems.

1.4. **Presentation**

These guidelines are presented in the following sections :

- i) Section 1: Introduction
- ii) Section 2: General Approach
- iii) Section 3: Requirements of different classes of Quality Assurance
- iv) Section 4: Typical Quality Assurance Plan for Construction and Design
- v) Section 5: Typical Proforma

At the end of the guidelines, definitions and terminology are given as an Annexure.

SECTION 2

GENERAL APPROACH

2.1. Concept

The term 'quality' has been defined as the totality of features and characteristics of a product or services that bear on its ability to satisfy stated or implied needs. In the contractual environments needs/requirements are specified, whereas in other environments implied needs/requirements should be identified and defined. The code of practice endeavours to meet the requirements by a three pronged strategy. Firstly, it specifies the acceptable materials of construction outlining the various tests of acceptance; secondly, it define various design criteria practical rules and sound engineering practices for guiding the designers in arriving at appropriate structural solutions; and thirdly, it deals with the workmanship and other aspects of construction which ensure that the design intents are realised in actual construction. The contract documents and technical specifications define the inter-relation of various parties to the contract as well as the requirements of quality. All these strategies implicitly depend upon human skill for their successful and reliable application.

The total system of policy, management responsibility, internal and external control, testing and quality control, acceptance criteria, corrective action, and documentation is covered in the quality system. It also encompasses the overall organisational structure, responsibilities, procedures and processes for implementing quality management. The aspect of overall management functions that determines the quality policy and implements it by such means as quality planning, quality control and quality assurance within its quality system, is referred to as 'Quality Management'.

The terms used in the field of quality management have acquired specific meanings and applications, different from the generic definitions found in dictionaries. Internationally accepted definitions and terminology have been included in **Annexure**, which also gives corresponding usage in relation to bridge projects. The 'purchaser' or 'customer' is the term used for those who place order for the 'product' or 'service' and the term 'supplier' for those who undertake to procure/produce/supply the same. The quality of the product (or service) is ensured and maintained by following a documented 'Quality Plan' which sets out specific quality practices, including 'Quality Control' which are operational techniques of controlling quality. 'Quality Assurance' (QA) includes all those planned actions necessary to provide adequate confidence that the product (or service) will meet the requirements, and is essentially a system of planning, organising and controlling human skills to assure quality. Quality Assurance Plan sets out the planned actions required for quality assurance. The continuous monitoring and verification of the status of QA activity to ensure that it is being followed is called 'Quality Surveillance'. 'Quality Policy' is a formally documented statement of management's intentions and directions as regards quality. 'Quality Audit' is a managerial tool used for reviewing the whole or a part of the quality system by internal or external agencies not connected with the operation of QA plan. 'Total Quality Management' brings to these concepts a long term global management strategy to achieve and improve quality and calls for the participation of all members of the organisation for the benefit of the organisation itself, its members, its customers and society as a whole.

2.2. Principal Components of Quality System

Implementation of quality system involves the following principal components :

i) Supplier's Quality Policy

Commitment of the management of supplier to achieve and sustain quality of the product or service to meet purchaser's stated or implied needs, whether contractually required or not.

ii) Purchaser's Quality Policy

Commitment of the management of the purchaser to obtain quality product or service to meet his stated or implied needs. This includes quality plan of the purchaser to satisfy himself about the quality of end product.

iii) **Internal Quality Systems**

Internal quality systems of all concerned organisations including quality plan, quality assurance, control of non-conforming products, quality audits and corrective actions.

iv) **Inspection and Audit**

Inspection and audit of internal quality systems, mutually conducted quality control tests, or independently conducted testing by third party and certification, so as to give confidence to purchaser or his appointed agent, when required by contract.

2.3. **Requirements of Quality System**

The requirements of quality system as given below are aimed primarily at achieving owners satisfaction by preventing non-conformity.

i) **Management Responsibility**

The supplier's management shall be responsible for quality policy. This will include resource mobilisation, organisation of personnel defining clearly the responsibility, authority and inter-relation for performance, management and verification functions, lines of reporting, control of non-conforming product and review and updating.

ii) **Quality System**

The supplier shall establish, document and maintain a quality system including quality plans, quality manual and procedures.

iii) **Contract Review**

Supplier shall establish and maintain procedures for contract review to ascertain that the requirements are adequately specified and understood and differences are resolved and recorded. He shall also ensure that he has the capability to meet the contractual requirements.

iv) **Design Control**

Supplier (Designer) shall establish and maintain documented procedures to control and verify the design to ensure that specified requirements are met. These should cover the aspects of design input, design activity, design output, design review, design verification, design changes, and design validation.

v) **Document and Data Control**

The supplier shall establish and maintain documented procedures to control all documents and data which relate to the requirements of these guidelines.

This control shall ensure that obsolete documents are promptly replaced. The changes/modifications to documents should be promptly informed to all concerned and documents re-issued incorporating changes.

vi) **Purchasing**

The supplier shall establish and maintain documented procedures to ensure that purchased product conforms to specified requirements. Evaluation of sub-contractors, maintenance of purchasing data and verification of purchased product, constitute important components of this requirement.

vii) Control of Customer Supplied Products

The supplier shall establish and maintain documented procedures for the control of verification, storage and maintenance of customer-supplied products, provided for incorporation into the supplies or for related activities.

Verification by the supplier does not absolve the customer of the responsibility to provide acceptable product.

viii) Product Identification and Traceability

The supplier should maintain data and documentation, which allow product identification and traceability during all stages of production and delivery.

ix) Process Control

The supplier shall identify and plan the production, installation and processes that directly affect the quality and shall ensure that these are carried out under controlled conditions.

Documented procedures defining manner of production, use of equipment, compliance with reference to standards/codes, monitoring, control and approval of processes and workmanship constitute important components of process control.

Special situations where the quality of results cannot be fully verified by subsequent inspection/testing of the processes shall be carried out by qualified operators and/or shall require continuous monitoring and control of process parameters to ensure that the specified requirements are met.

x) Inspection and Testing

The supplier shall establish and maintain documented procedures for inspection and testing of activities in order to verify that specified requirements for the products are met.

Incoming product should not be used by supplier, prior to inspection and testing. However, in exceptional situations where it is thus used, it shall be positively identified and recorded in order to permit recall and replacement in the event of non-conformance to specified requirements.

In-process inspection and testing shall be carried out as required by quality plan and/or documented procedure.

The final inspection and testing shall be carried out in accordance with quality plan and/or documented procedures to complete the evidence of conformance of the finished product to specified requirements.

No product shall be dispatched until all the activities of the quality plan have been satisfactorily completed. Where product shall fail to pass any inspection and/or test, the procedures for control of non-conforming product shall apply. Records shall identify the inspection authority responsible for release of product.

xi) Control of Inspection, Measuring and Testing Equipment

Documented procedures to control, calibrate and maintain inspection, measuring and testing equipment shall be established and maintained. The equipments should be kept in good operating condition, calibrated at the specified frequency, and used as per instructions. All records about the equipment, including its identification, calibration, malfunction, repair and certification should be maintained.

xii) **Inspection and Test Status**

The inspection and test status of products shall be identified by suitable means, which indicate conformance or non-conformance of product with regard to inspection and tests performed. Records shall be maintained to identify inspection and test status.

xiii) **Control of Non-Conforming Products**

The supplier shall establish and maintain procedures to ensure that non-conforming product is prevented from inadvertent use or installation.

Non-conforming product shall be reviewed in accordance with the documented procedures for :

- a) Reworking to meet the specifications,
- b) Accepted with or without repair with concession,
- c) re-graded for alternative use, or
- d) rejected/scrapped.

These activities and their results should be fully documented.

xiv) **Corrective and Preventive Actions**

The supplier shall establish and maintain documented procedures for taking corrective and preventive actions to eliminate the causes of actual or potential non-conformities to a degree appropriate with the risks. This would include investigation of causes of non-conformities and recording of any changes to the documented procedures resulting from such actions.

xv) **Handling, Storage, Packaging, Preservation and Delivery**

The supplier shall establish document and maintain procedures for handling, storage, packaging, preservation and delivery of product.

The supplier shall arrange for the protection of the quality of product after final inspection and test. Where contractually specified, this protection shall be extended to include delivery to destination.

xvi) **Control of Quality Records**

The supplier shall establish and maintain documented procedures for identification, collection, indexing, access, filing, storage, maintenance and disposition of quality records. Quality records shall be maintained to demonstrate conformance to the required quality and the effective operation of the quality system. Pertinent sub-contractor's quality records shall be an element of these data.

Retention times of quality records shall be established and recorded. Where agreed contractually, quality records shall be made available for evaluation by the purchaser or his representative for an agreed period.

xvii) **Internal Quality Audits**

The supplier shall establish and maintain documented procedures for planning and implementing internal quality audits to verify whether quality activities comply with planned arrangements and to determine the effectiveness of the quality system.

Internal audits shall be scheduled on basis of the status and importance of the activity to be audited.

The management personnel responsible for the area shall take timely corrective action on the deficiencies found by the audit.

xviii) Training

The supplier shall establish and maintain procedures for identifying the training needs and provide for the training of all personnel performing activities affecting quality. Personnel performing specific assigned tasks shall be qualified on the basis of appropriate education, training, and/or experience as required. Appropriate records of training shall be maintained.

xix) Servicing

Where servicing is specified in the contract, the supplier shall establish and maintain procedures for performing, verifying and reporting that servicing meets the specified requirements.

xx) Statistical Techniques

Where appropriate, the supplier shall establish procedures for identifying need for statistical techniques required for controlling and verifying process capability and product characteristics.

2.4. Quality Assurance and Quality Assurance Manual

Quality Assurance (QA) is defined as all the planned and systematic activities implemented within the Quality System and demonstrated as needed, to provide adequate confidence that an entity will fulfill the requirements. A Quality Assurance Manual provides a base document outlining policy, procedures, responsibilities, compliance, acceptance criteria and documentation. It should be prepared and accepted by all parties concerned before start of project.

It should generally cover the following :

- a) Identification of all parties involved in QA and their inter-relationship.
- b) Internal QA system of each party.
- c) Levels of cross-checking/verification in case of multiple verifications/controls, including systems of inspection and audit, wherever applicable.
- d) Organisation of personnel, responsibilities and lines of reporting for QA purposes.
- e) Criteria for acceptance/rejection, including identification of proper authorities for such decisions.
- f) Inspection at the end of defect liability period.
- g) Items to be covered in maintenance manual.
- h) All formats for documentation.

Though several parties may be involved in enforcing quality assurance for any particular item of work or a product, the ultimate responsibility of compliance with QA Manual and of achieving required quality generally rests with one party. When process and/or product control is carried out by the supplier/producer or his agent, it is termed as internal control or 'one level' control. For important items of work, independent parallel checks/supervision are carried out by one or more agencies, either on full scale or on sample basis. This is normally carried out as external control or second level control. In some cases, third level of control may also be required such as that by a regulatory body or by insurance agency. These levels of control should be clearly defined in the Quality Assurance Manual. The Manual should also identify the responsible parties, their functions and inter-relation between them.

2.5. Classes of Quality Assurance for Bridges

Depending upon the levels of checking/cross-checking and controls, required to provide adequate confidence, four classes of quality assurance are mentioned below :

Classes of Quality Assurance	Class Nomenclature
1. Nominal QA	Q-1
2. Normal QA	Q-2
3. High QA	Q-3
4. Extra High QA	Q-4

Since the degree of requirement of confidence for bridge construction is very high, nominal QA i.e. Class Q-1 shall not be permitted in bridge construction. Thus there will be only three classes of QA for bridge construction, namely Q-2, Q-3 and Q-4.

A consistent set of quality assurance activities adopted for different operations will lead to achievement of one of the three classes mentioned above. The detailed description of the controls falling in the above three QA classes for various activities are given in Section 3. Once a desired overall quality class is chosen for a bridge project, the minimum degree (level) of controls in various activities should be as indicated in Section 3 for the respective class. This, however, does not preclude raising the degree of controls for some of the items only (thereby partially adopting a higher class for such items), if the particular upgradation is considered necessary. For simplicity of classification, however, such partial upgradation shall not be deemed to increase the overall class of QA.

2.6. Guidelines for Selection of QA Class for Bridge Projects

Prior to the commencement of 'project preparation' stage, one of the three QA classes should be tentatively chosen for the project. This classification should be reviewed depending on site specific problems and types of solutions being evolved. At this stage, the final selection of the overall QA class of the project should be made. Simultaneously decision regarding upgradation of class for some of the activities, if found necessary, should also be made.

The following guidelines are given for selection of appropriate QA class for bridges. The word 'bridges' includes flyovers, culverts and all such structures carrying road traffic.

- 1) No bridge should have QA below class Q-2.
- 2) Q-2 class of QA can be adopted for following categories of bridges
 - a) Bridges upto 60 m length and having individual span length not exceeding 20 m.
 - b) Bridges having deck area upto 480 sq.m.
 - c) Construction materials: Plain or Reinforced Concrete.

In order to cater to specific problems, some of the activities may be raised to Q-3 class.

- 3) Q-3 class of QA can be adopted for following categories of bridges
 - a) Bridges having spans exceeding 20 m.
 - b) Bridges having lengths more than 60 m, having individual span lengths not exceeding 45 m.
 - c) Bridges having deck area exceeding 480 sq.m.
 - d) Construction materials: Plain Concrete, Reinforced Concrete or Prestressed Concrete.

For bridges across rivers which are shifting in nature or which present some problems of stability, and/or those having special foundation problems, some of the activities may be raised to higher class.

- 4) Q-4 class of QA can be adopted for following categories of bridges
 - a) Bridges built with innovative design/construction/materials such as those using very large spans, cable stay concept, high performance concrete, new prestressing systems etc. Separate quality assurance manual as appropriate to cover such design, materials/construction techniques should be prepared and defined in the tender document.
 - b) Bridges at locations where no alternative routes are available nearby, or where disruption to traffic over long period is unacceptable, and where repair/replacement cost are considered very high.

2.7. Quality Assurance Manual for Bridges

2.7.1. The owner, consultant, approving authority, main contractor, material supplier, manufacturers of items to be incorporated in the structures, specialist/nominated sub-contractors and equipment manufacturers are the parties involved in the overall QA system for bridge construction.

Typical organisational structure for various parties involved in design and construction (owners as well as contractors) are given in Figs. 2.1, 2.2 & 2.3.

2.7.2. Various activities on a bridge project can be classified under three major groups :

- i) Design
- ii) Construction
- iii) Manufacturing

2.7.2.1. In design activity, purchaser is the authority who places the order for design and/or project preparation. It may be either the owner of the bridge as in the case of preparation of detailed design, or the contractor, as in the case of 'design and construct' contracts. Supplier is the consultant who undertakes to prepare the design. The design, drawings and tender documents are the end products. The QA manual should cover those requirements of Quality System, which primarily concern 'services' or 'expertise'.

2.7.2.2. In construction activity, purchaser is the authority who places the order for construction of bridge. Supplier is the contractor who undertakes to construct the bridge. The bridge itself is the end product.

2.7.2.3. The manufacturing activity falls in the following two categories:

The first category consists of factory manufactured items of general use such as cement, reinforcing steel, prestressing steel, admixture and the like. Quality assurance of the manufacturing processes of those items need not be covered under the quality assurance manual for bridges. However, the requirements of quality system pertaining to the specifications of quality, testing and acceptance procedure, procurement, storage, traceability and such other relevant items, which are to be carried out by owner/designer/contractor, should be covered therein.

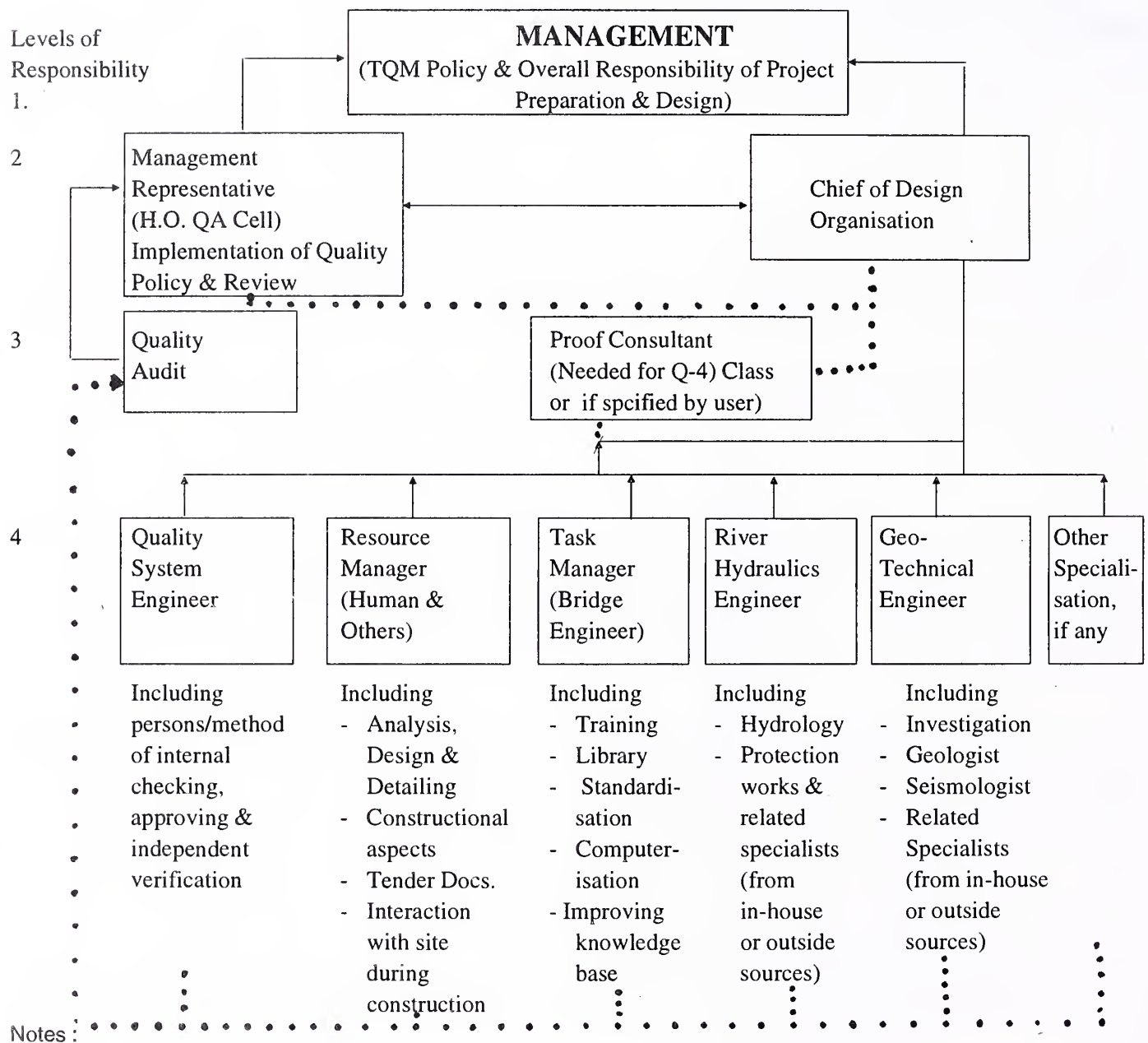
The second category of manufactured items cover prestressing anchorages, bearings, expansion joints, hand rails and the like, which are manufactured by specialist suppliers and are purchased and used as a finished product in the bridge by the contractor. The quality assurance manual should cover the quality assurance of the manufacturing of such items.

2.7.3. Main aspects of activities which affect the quality of a bridge are highlighted below :

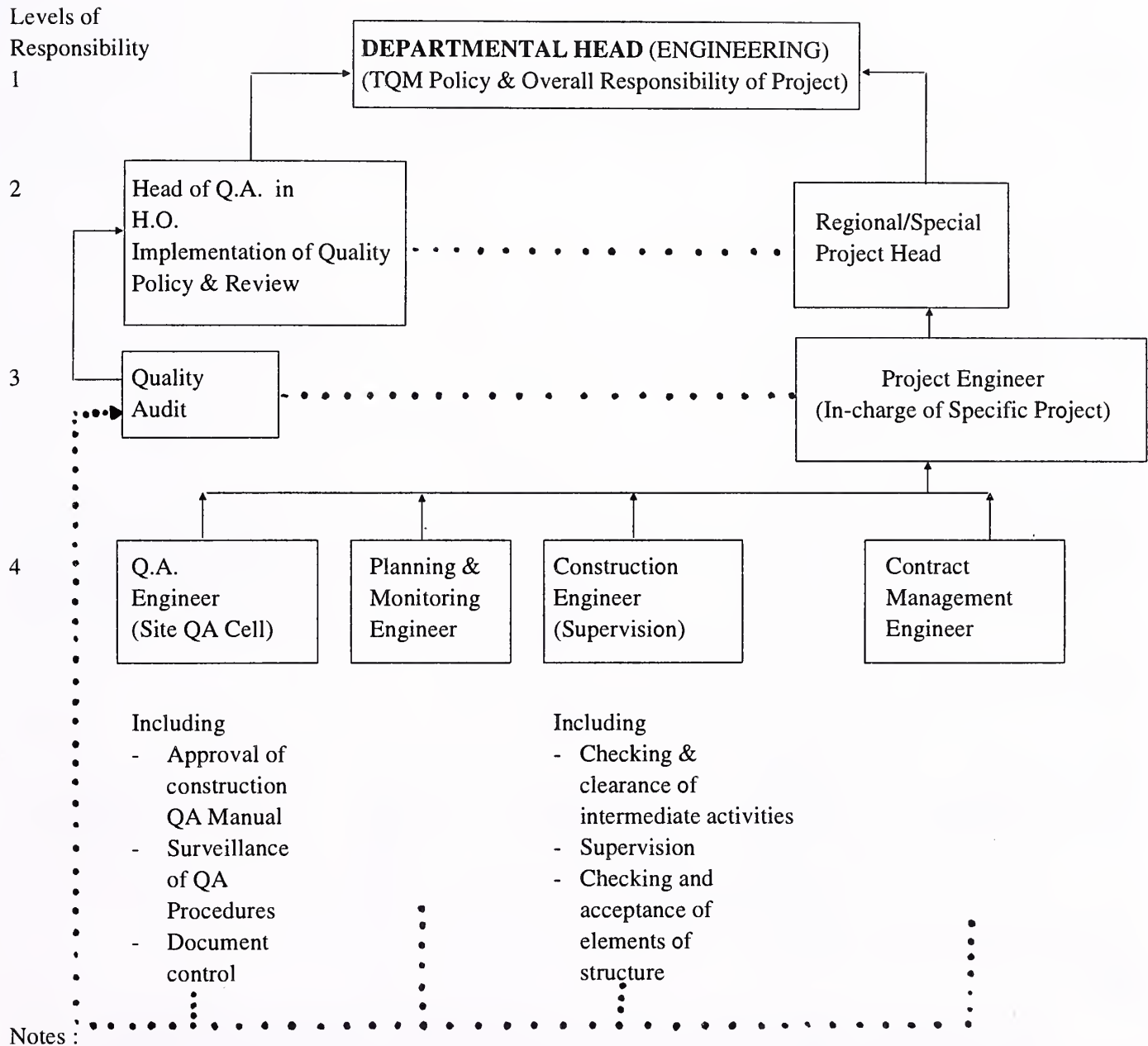
Activity	Main Aspects Affecting Quality
A. Project Preparation (Data collection, selection of suitable options, project document)	<ul style="list-style-type: none"> i) Adequacy and accuracy of data, and surveys (including materials survey); reliability of data and source; and documentation. ii) Solutions based on codes and practices, taking into account for relevant local and past experience, and documentation. iii) Documentation of all alternatives considered. iv) Review before finalisation.

Fig. 2.1

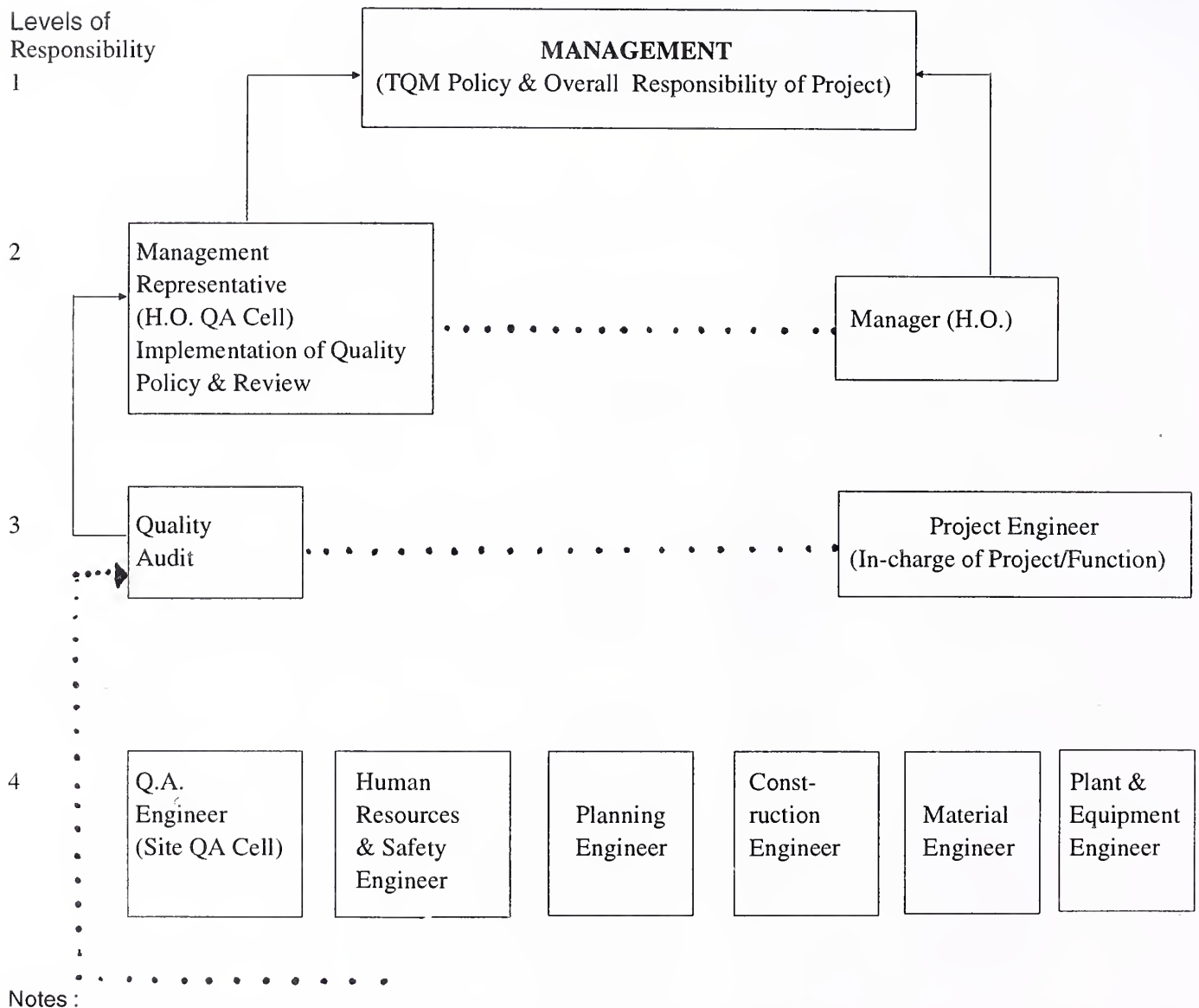
**Q.A. ORGANISATION FOR DESIGN
(Owner, Consultant/Contractor)**



1. The Organigram indicates levels of responsibility in four rows. The lines of reporting for execution of work and responsibility for quality are shown by full lines and arrow heads. The working level interactions are indicated by dotted lines. The decisions concerning relative priorities, and about differences between equal levels are to be taken at higher level of responsibility.
2. For Q-3 and Q-4 QA classes, the responsibilities shown in each box need separate group of personnel with group-head.
3. For Q-4 class, additional specialisations may be involved, which need to be suitably added. The external specialist agencies may have to play bigger role for Q-4 class and special attention is needed to integrate their work and have proper QA requirement of 'purchase'.
4. For Q-2 class work, the QA activities at one level may be clubbed in one or more groups and the responsibility of the same entrusted to respective head/s.

Fig. 2.2**Q.A. ORGANISATION FOR CONSTRUCTION
(OWNERS)**

1. The Organigram indicates levels of responsibility in four rows. The lines of reporting for execution of work and responsibility for quality are shown by full lines and arrow heads. The working level interactions are indicated by dotted lines. The decisions concerning relative priorities, and about differences between equal levels are to be taken at higher level of responsibility.
2. For Q-3 and Q-4 QA classes, the responsibilities shown in each box need separate group of personnel with group-head.
3. For QA classes Q-2, some or all activities at one level may be clubbed in one or more groups and the responsibility of the same entrusted to respective head/s.
4. Instead of Head of QA (Level 4) being a separate wing, it is also possible to make it a part of the office of Regional/Special Project Head.

Fig. 2.3**Q.A. ORGANISATION FOR CONSTRUCTION
(CONTRACTORS)**

1. The Organigram indicates levels of responsibility in four rows. The lines of reporting for execution of work and responsibility for quality are shown by full lines and arrow heads. The working level interactions are indicated by dotted lines. The decisions concerning relative priorities, and about differences between equal levels are to be taken at higher level of responsibility.
2. For Q-3 and Q-4 QA classes, the responsibilities shown in each box need separate group of personnel with group-head.
3. For QA classes Q-2, some or all activities at one level may be clubbed in one or more groups and the responsibility of the same entrusted to respective head/s.

- B. Design and drawings
- i) Detailed Design Basis Report
 - ii) Detailed designs, documentation and cross-checking.
 - iii) Review for constructability and availability of intended construction expertise.
 - iv) Internal review before finalisation, or proof checking.
 - v) Drawings, bar bending schedules and stressing schedules giving sufficient, unambiguous and clear details specially with regard to assumptions made in the design. Limits of variations in assumptions beyond which reference should be made to the designer, shall also be indicated.
 - vi) Provision of facilities for carrying out inspection, maintenance and repair/strengthening and replacement of certain parts (e.g. bearings, expansion joints etc.)
- C. Preparation of Contract Documents
- i) Standardised general conditions of contract including enforceable defect liability clauses, procedures for decision making, in-built mechanism for settlement of disputes, appropriate financial conditions and reasonable payment schedules.
 - ii) Standardised detailed technical specifications.
 - iii) Stipulations of the type and capacity of essential of equipment to be used.
 - iv) Provision and availability of required facilities at site.
 - v) Stipulations with regard to project organisation of contractor as well as the project management organisation of the owner.
 - vi) Stipulation for preparation for QA manual.
 - vii) Stipulations for submission of completion report with all supporting documents and 'as - built' drawings.
- D. Organisation and Management of Suppliers/Contractors
- i) Management's Quality Policy
 - ii) Qualified and experienced technical work force and deployment of trained supervisors/workmen in adequate strength.
 - iii) Preparation of Quality Assurance Manual including provision for quality audit.
 - iv) Mobilisation of adequate resources including suitable plant and equipment and items of falsework.
 - v) Continuous planning, review and corrective action.

- | | | |
|----|--|---|
| | | vi) Adequate financial input including cash-flow and fund management. |
| | | vii) Prequalification of sub-contractors/suppliers. |
| E. | Material Procurement | |
| | | i) Material specifications, including stipulations of Q.C. tests and acceptance/rejection criteria. |
| | | ii) Quality assurance plan defining documentation with special stress on traceability. |
| F. | Production of items and sub-items of construction (like concrete, reinforcement, prestressing cables etc.) | |
| | | i) Adequate stipulations regarding workmanship. |
| | | ii) Drawings and other documents giving design intent. |
| | | iii) Ensuring adequate supervision and quality assurance. |
| | | iv) Inspection and quality surveillance. |
| | | v) Deployment of proper and adequate plant and equipment. |
| | | vi) Relevant items covered in (D) & (E) above. |
| G. | Management and Organisation of Owners | |
| | | i) Management's quality policy |
| | | ii) Project specific Q.A. plan |
| | | iii) Project organisation including deployment of competent personnel. |
| | | iv) Ensuring adequate supervision and quality surveillance. |
| | | v) Provision for quality audit. |

SECTION 3

QUALITY ASSURANCE REQUIREMENTS OF DIFFERENT CLASSES OF QUALITY

3.1. General

This section contains detailed guidelines indicating requirements of different classes of quality for bridge projects. The selection of a class for projects is discussed in Section 2. The requirements of quality control and level (degree) of control are given in Table 3.1 under six sub-heads, as follows:

- 1) Project Preparation
- 2) Design and Drawings
- 3) Contractual Aspects
- 4) Construction Organisations
- 5) Materials
- 6) Workmanship

Aspects of project preparation as well as designs and drawings have been covered briefly, and are indicative of the general approach. However, the aspects of construction affecting quality are covered in greater detail.

3.2. Project-Specific QA Plan

The contents of the table provide broad check list of various activities for a typical bridge project. Based on this table and QA class chosen in accordance with Section 2 a detailed 'project-specific' quality assurance plan shall be prepared in each case. All relevant factors must be considered in detail before finally choosing the overall quality assurance class for a particular project or even for particular activities within the project itself, taking into account the consistency of the QA requirements for all critical components of the bridge. Such QA plan is normally prepared by the owner, or by construction agency, and when prepared by the latter, it is scrutinized and approved by the owners or the consultants to the project. The QA plan shall be documented in the form of QA Manual. The QA plan/manual so prepared should form part of the contract agreement. A typical QA plan for construction activities is illustrated in Section 4.

3.3 Implementation

Implementation of quality assurance plan may be carried out by the following methods :

- 1) Internal control by the construction agency
- 2) External control either by the owners or by the third party inspection agency.

The choice of agency for enforcement of quality assurance plan should preferably be spelt out in the tender documents.

TABLE 3.1
QUALITY ASSURANCE REQUIREMENTS

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
1.	PROJECT PREPARATION			
1.1	Adequacy and reliability of data	<ul style="list-style-type: none"> - Data collection from primary local sources either in-house or through other agencies. - Verification and certification at local level within the organisation. 	<ul style="list-style-type: none"> - Data collection from primary local sources and cross checking by other methods either in-house or through specialised survey and investigation agencies. - Verification and certification at senior or central level within the organisation. 	<ul style="list-style-type: none"> - As in Q-3, but supplemented by verification and checks through other expert agencies and use of more sophisticated methods.
1.2	Q.A. Systems & Documentation	<ul style="list-style-type: none"> - Project prepared and approved following QA principles and in-house checking and verification. 	<ul style="list-style-type: none"> - As in Q-2, but independent checking and review through a separate in-house unit, or through external organisation. 	<ul style="list-style-type: none"> - As in Q-3 but independent checking and review by an external organisation is essential.
2.	DESIGN & DRAWINGS			
2.1	Organisation	<ul style="list-style-type: none"> - Owner's in-house/consultants/contractors design offices with established internal QA procedures. 	<ul style="list-style-type: none"> - As in Q-2, but independent checking and review through an in-house unit or through external organisation. 	<ul style="list-style-type: none"> - As in Q-3, but checking and review by an external organisation is essential.
2.2	a) Drawings	<ul style="list-style-type: none"> - Can be based on type design with necessary notes to cover variation. 	<ul style="list-style-type: none"> - Project specific drawings made at pre-execution stage indicating limits of validity of details given on the drawing. 	<ul style="list-style-type: none"> - Same as Q-3

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
	b) Bar Bending Schedules, Cable layout & stressing schedule	<ul style="list-style-type: none"> - Drawings giving full details issued after internal checking. - Bar Bending Schedules, full details of cable layout & stressing schedule to be given by designer, and verified at site by constructor. 	<ul style="list-style-type: none"> - Same as Q-2. 	<ul style="list-style-type: none"> - Same as Q-2
2.3	Design Review & Proof Checking	<ul style="list-style-type: none"> - Designs may be submitted for checking by in-house but independent design unit. 	<ul style="list-style-type: none"> - As in Q-2, but independent design checking and review through an in-house unit or through external organisation. 	<ul style="list-style-type: none"> - As in Q-3, but checking and review by external organisation is essential.
2.4	Design Modifications due to site variations or substitute materials and other reasons	<ul style="list-style-type: none"> - Design notes should clearly state the limits of validity of drawings. - Reference should be made to design office for changes. 	<ul style="list-style-type: none"> - As in Q-2, but all changes incorporated in revised drawings & re-issued within reasonable period. 	<ul style="list-style-type: none"> - Same as Q-3
2.5	As built drawings	<ul style="list-style-type: none"> - As built drawings essential. 	<ul style="list-style-type: none"> - As in Q-2, but all changes incorporated in revised drawings & re-issued within reasonable period. 	<ul style="list-style-type: none"> - Same as Q-3.
2.6	Maintenance of As-built Drawing, design, specification & construction information.	<ul style="list-style-type: none"> - To be maintained by owner, and maintenance agency. 	<ul style="list-style-type: none"> - As in Q-2, but full record to be maintained in addition at central office for govt. departments. 	<ul style="list-style-type: none"> - As in Q-3, but additionally records to be maintained also by microfilming/digital storage methods.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
2.7	Model Tests/Proto-type Test			
	a) River hydraulics	- Not ordinarily necessary.	- If necessary should be carried out before finalisation of design.	- Same as Q-3.
	b) Structural model test	- Not ordinarily necessary.	- If necessary should be carried out before finalisation of design.	- As in Q-3, but are essential for specific special items (e.g. new developments) in addition to analytical solutions.
	c) Non-destructive testing (ultra-sonic, radio-graphy, etc.)	- Not ordinarily necessary.	- ND testing on sample basis by owner/appointed agency for checking achievement of quality is to be encouraged.	- As in Q-3, but ND testing on larger scale to be encouraged (specialist agencies to be mobilised if required).
3.	CONTRACTUAL ASPECTS (Contract document)			
3.1	a) Prequalification (Main Contractor)	- From approved list of contractors.	- Preferable to prequalify contractors on the basis of PQ applications.	- Prequalification essential.
	b) Suppliers/Sub-Contractors	- Approval during course of work by appropriate authority.	- Prequalification prior to engaging the sub-contractor.	- Same as Q-3.
	c) Nominated Sub-contractor/agency	- Ordinarily not required.	- Where required it shall be specified in tender.	- Same as Q-3.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
3.2	a) Specifications and Contract Documents	<ul style="list-style-type: none"> - Following standard general items of work and specifications. If special specifications are needed for any item of work follow Q-3 level for the same. Complete contract document should be easily accessible. 	<ul style="list-style-type: none"> - Complete contract documents with full specifications including all relevant codes should be available at site at all times. Specifications for non-standard items to be detailed, finalised and cleared at appropriate level of responsibility. 	<ul style="list-style-type: none"> - Same as Q-3.
3.3	b) Prebid meeting QA Manual	<ul style="list-style-type: none"> - Not applicable. - Requirements can be covered in tender document. 	<ul style="list-style-type: none"> - Preferable. - As in Q-2, in addition contractor to submit and get approved the QA manual defining all activities with minimum two levels of controls. Each of the controlling authority to have their own QA manual covering their responsibilities. 	<ul style="list-style-type: none"> - Essential. - As in Q-3, but with minimum three level of controls, for specialised/innovative items.
3.4	Defect liability period. (Responsibilities of owner & contractor should be defined in the tender document).	<ul style="list-style-type: none"> - Minimum 1 year. - For manufactured items appropriate defect liability period to be specified. 	<ul style="list-style-type: none"> - One year in general and longer as appropriate for special items of work. - Same as Q-2. 	<ul style="list-style-type: none"> - Same as Q-3. - Same as Q-2.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
4.	CONSTRUCTION ORGANISATIONS			
4.1	Organisation of contractor	<ul style="list-style-type: none"> - Contractor's execution staff responsible for both supervision and surveillance of quality, with external agency/owner for audit of quality plan and its operation. 	<ul style="list-style-type: none"> - As in Q-2, but with separately set up QA group for operation of quality plan. 	<ul style="list-style-type: none"> - As in Q-3, with additional external quality surveillance and audit.
4.2	Organisation of Owner/ Project Management Consultant (PMC)	<ul style="list-style-type: none"> - Owner may have his own execution staff responsible for supervision/surveillance of quality. If not, appoint outside agency as PMC. 	<ul style="list-style-type: none"> - As in Q-2, but with specially set-up QA group for operation of quality plan. 	<ul style="list-style-type: none"> - As in Q-3, with additional external quality surveillance and audit.
4.3	Planning of construction activities	<ul style="list-style-type: none"> - Board planning made by constructor and got approved from owner/PMC. - Deployment of skilled labour. - Execution of work only after prior intimation to owners supervisory representative. - Use of Bar Charts recommended. 	<ul style="list-style-type: none"> - As in Q-2, but with construction activities planned in details including material planning, sequencing of work, identifying requirement of skilled labour, supervisory staff and methods of quality control. - Use of bar chart or PERT/ CPM techniques and regular review as part of monitoring and replanning activity. 	<ul style="list-style-type: none"> - As in Q-3, with involvement of designer/specialist consultant for work planning of innovative aspects. - As in Q-3, with monitoring by special cell set up by owner.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
4.4	Supervision	<ul style="list-style-type: none"> - Full time supervisors for all construction activities. - Periodic visits by designer/owner. 	<ul style="list-style-type: none"> - As in Q-2, with additional full time supervision by second independent agency (owner or consultant). 	<ul style="list-style-type: none"> - As in Q-3, with additional specialist level supervision for innovative aspects.
4.5	Quality Surveillance and Audit	<ul style="list-style-type: none"> - Quality surveillance by constructors' qualified engineers, and owners' supervisory representative. 	<ul style="list-style-type: none"> - As in Q-2, but by separate QA cells of constructor and owner/PMC (two level QA) following format and documented quality plan. - Regular surveillance and audit are essential. 	<ul style="list-style-type: none"> - As in Q-3 with special audit for efficacy of innovative aspects.
5.	MATERIALS			
5.1	General			
	a) Materials from natural sources	<ul style="list-style-type: none"> - Small or medium scale purchases from large and established suppliers/ traders. - Sources mutually agreed to between contractor and owners' project teams and documented. - May rely on local experience and knowledge of the past performance for coarse and fine aggregates and water. 	<ul style="list-style-type: none"> - As in Q-2. Also bulk purchase from source. - Independent testing/acceptance by contractors' & owners' Q.A. teams and documented. - Testing/acceptance at the start of the project as well as at specified frequency. 	<ul style="list-style-type: none"> - As in Q-3, but may also set up own source for supply. - As in Q-3, but with additional (third level) testing/acceptance by independent agency (such as PMC or Approved Testing Laboratory) - Same as Q-3.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
	b) Factory manufactured items including cement, steel bearings, expansion joints etc.	<ul style="list-style-type: none"> - Manufacturer's tests certificate accepted with sample check by independent agency for incorporation in structure. - ISO:9000 certificate not essential for manufactured items. 	<ul style="list-style-type: none"> - Manufacturer's test certificates with sample checks for initial acceptance only. - Regular testing at specified sampling frequency during construction. - Set up mutually agreed QA methods at two levels for inspection/testing to cover the specific purchase order. - In case the manufacturer has ISO:9000 certification, he may be given preference. 	<ul style="list-style-type: none"> - Same as Q-3. - As in Q-3, but may also have additional independent QA checks at source (third level check). - As in Q-3, but third level checking by appointment of specialised agency for innovative aspects. - As in Q-3.
	c) Records for all materials	<ul style="list-style-type: none"> - Record of sources and purchase dates for all items. For manufactured items record of manufacturers' test certificate. 	<ul style="list-style-type: none"> - As in Q-2. Also record of issue of manufactured materials and location of use. 	<ul style="list-style-type: none"> - Same as Q-3.
	d) Testing facilities	<ul style="list-style-type: none"> - Testing from nearby established test houses/laboratories. 	<ul style="list-style-type: none"> - Physical testing facilities at site. For chemical & Special tests as per Q-2. Use of chemical testing kits for quick checks at site are to be preferred. 	<ul style="list-style-type: none"> - As in Q-3, with properly equipped testing facilities & laboratory at site under control of QA personnel of contractor & owner (independent of production team).

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
5.2	a) Aggregates Coarse Aggregates			
	- Grading	- At the beginning for mix design & for every change of source.	- At the beginning for mix design and for every change of source/stack and for every major structural element.	- As in Q-3, but if necessary with increased frequency, (testing at site laboratory).
	- Other physical tests (crushing value abrasion moisture contents etc.)	- For selection of source if in doubt.	- At the beginning for mix design and for every change of source.	- As in Q-3 (two level checks at site laboratory).
	- Deleterious contents	- For selection of source if in doubt.	- Mandatory for selection of source and whenever there is change in source of supply.	- Same as Q-3.
	- Aggregate reactivity	- Not applicable.	- Mandatory for selection of source and whenever there is change in source of supply.	- Same as Q-3.
	b) Fine Aggregate (sand)			
	- Grading	- At the beginning for mix design & every change of source.	- At the beginning for mix design and for every stack, change of source/for every major structural element mix.	- As in Q-3, but if necessary with increased frequency, (testing at site laboratory).
	- Other physical tests (crushing value, abrasion, moisture contents etc.)	- For selection of source if in doubt.	- At the beginning for mix design and for every change of source.	- As in Q-3 (two tier checks at site laboratory).

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
5.3	- Deleterious Contents	- For selection of source if in doubt.	- Mandatory selection of source and whenever there is change in source of supply.	- Same as Q-3.
	- For control of chlorides etc.	- Simple but frequent chemical checks at site for effectiveness. - External laboratory checks/control (two level control).	- As in Q-2.	- As in Q-2, supported by checking at Testing laboratory at site.
	Water			
5.4	- Suitability	- At the beginning.	- Same as Q-2.	- Same as Q-2.
	- Chemical analysis	- Carried out if in doubt.	- Mandatory at the beginning of project and repeated (for chlorides and sulphates) in between if any change is perceived/suspected in water quality (including seasonal changes).	- As in Q-3, but at increased frequency during working.
5.4	Cement			
	- Normal Physical and chemical tests	- Manufacturers certificate acceptable & testing in case of doubt or non-availability of certificate.	- As in Q-2 and at frequency of each new consignment and documented. Special tests will be required for special cements.	- As in Q-3. Testing carried out at site laboratory and independently cross-checked at predetermined frequency.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
5.5	- Form of purchase, storage, transportation, and use within acceptable time limit	- Trade Purchases, intermediate storage in dry and covered place, transportation and use of factory filled, machine stitched bags.	- Supply from factory with direct transportation from factory to site godown/silos. Transportation and trans-shipment supervised and documented.	- Same as Q-3.
	Admixtures			
	a) Approval	- May be permitted under specialist supervision in which case follow Q-3 controls.	<ul style="list-style-type: none"> - Independently carried out acceptance testing after field trials for each sources. - Re-trials with change in Source of Cement - Routine checking by testing for every batch of admixture. - Manufacturers' data/certificate acceptable as basis of comparison for production lot. 	<ul style="list-style-type: none"> - As in Q-3, with additional independent tests, i) Chloride contents. ii) Spectroscopic signature of accepted product as basis of comparison for production lots.
	b) Dosage dispensing and production controls at site	<ul style="list-style-type: none"> - Dosage to be finalised after field trial mixes, special mechanical devices to be used for dispensing. - Frequent checks for specific gravity. - Continuous monitoring of workability of concrete. 	- Same as Q-2.	- Same as Q-2.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
5.6	c) Training of site staff by manufacturer	<ul style="list-style-type: none"> - Visual inspection of concrete after striking forms for local defects (including delayed setting). - Proper training of site staff in use as well as quality control, plus periodic visits by manufacturer's expert. 	<ul style="list-style-type: none"> - Same as Q-2. 	<ul style="list-style-type: none"> - As in Q-2, but visits by experts at close frequency.
	Reinforcing Steel			
	- Normal Physical Tests	<ul style="list-style-type: none"> - Once at beginning and for every change in source in addition to manufacturer's certificate. 	<ul style="list-style-type: none"> - As in Q-2, and for each consignment. 	<ul style="list-style-type: none"> - As in Q-3, but further supplemented by random checking by QA team.
	- Chemical Composition	<ul style="list-style-type: none"> - Once at beginning, and if in doubt for any source. 	<ul style="list-style-type: none"> - Same as Q-2. 	<ul style="list-style-type: none"> - Same as Q-2.
	- Welding	<ul style="list-style-type: none"> - Not ordinarily permissible at site. 	<ul style="list-style-type: none"> - Welding to be done only by qualified and tested welders. - Types of electrodes to be specified for each purpose. - Random testing of welded joints for strength. 	<ul style="list-style-type: none"> - As in Q-3, but welders to be periodically tested and also welding to be examined by experts after destructive tests.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
5.7	Prestressing Steels/ Anchorage Systems and Cable-anchorage assembly :			
	a) General (for all items of pre-stressing including equipment)	- In a sealed and moisture proof godown with minimum openings store above ground level on raised supports or in racks.	- Same as Q-2.	- Same as Q-2.
	- Storage	- Such godown will have humidity control. In addition, vapour face inhibitors and/or water soluble oils to protect steel.	- Same as Q-2.	- Same as Q-2.
	- Compatibility of various components	- Suitability of anchorages for use with wires/ strands (meeting relevant specifications) to be certified by the manufacturer of anchorages. Also compatibility of all other materials and equipment to be thus certified/ cleared.	- Same as Q-2.	- As in Q-2, but compatibility established at site as required by QA team.
	- Methods of handling & caretaking	Also the manufacturer to supply special assistance at site, if required, to train and supervise personnel at work.	- Same as Q-2.	- Same as Q-2.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
	b) HT Wires/ Strands			
	- Mechanical Properties (Tensile Strength, Proof Stress)	- Manufacturer's Test Certificate can be accepted. Additional Testing if in doubt.	- In addition to manufacturer's certificate, tests done on random samples for a lot of 50 T, or part thereof and witnessed by independent QA team at random.	- As in Q-3, but for every coil. Sample testing witnessed by independent QA team at specified frequency.
	- Modulus of Elasticity	- Insist for manufacturer's certificate giving stress/strain curve and modulus of elasticity. Sample testing witnessed by independent QA team.	- Same as Q-2. - Modulus established initially (acceptance test).	- Same as Q-2. - Modulus established initially and verified by works test.
	- Relaxation Test	- Manufacturers' certificate.	- Testing & Certification essential for 1000 hours test by independent test house.	- As in Q-3. Also tests to be witnessed by contractors/owners QA team.
	- Chemical Composition	- Manufacturer's Certificate can be accepted with special testing, if in doubt.	- As in Q-2, plus testing by independent agency on random sample basis.	- Same as Q-3.
	- Packing	- Packing with two layer for waterproofing and mechanical protection.	- Same as Q-2.	- Same as Q-2.
	- Transportation	- Transport vehicle check. - Protection from environmental or physical damage.	- Same as Q-2.	- Same as Q-2.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
	<ul style="list-style-type: none"> - Suitability of coil size/weight for use at site c) Anchorage System (Chemical Composition Geometry & Heat Treatments, Supplementary Tests) d) Cable Anchorage Assembly (Acceptance Testing) - Static Tensile test & load transfer test. 	<ul style="list-style-type: none"> - Coils handled by mechanical devices prohibiting movement by rolling. - The wire/strand should be free of kinks or deformations and straight. - Contact with contaminated surfaces avoided. - Permitted using anchorage of established manufacturers of long standing based on certification of suitability & quality by manufacturer. - Not normally required. 	<ul style="list-style-type: none"> - Same as Q-2. - As in Q2 but supported by manufacturers detailed QA plan (which can be verified by purchaser if necessary). - Manufacturers certificate. - May additionally require testing at site or at independent laboratory as per FIP Guide. 	<ul style="list-style-type: none"> - Same as Q-2. - As in Q3, but in addition QA plans should be independently checked by QA team and verified at manufacturer's facilities. - Manufacturers certificate and certificate by testing at independent laboratory as per FIP Guide. Tests may be repeated at the beginning of the project with the proposed materials & witnessed by the representatives of contractor/owner.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
	<ul style="list-style-type: none"> - Dynamic Test for Cable/Anchorage assembly 	<ul style="list-style-type: none"> - Not normally required 	<ul style="list-style-type: none"> - Manufacturers certificate of testing. - Also independent laboratory testing as per FIP Code, once for new system of anchorages/cables. 	<ul style="list-style-type: none"> - As in Q3, plus any additional tests that a QA team may require.
	e) Sheathing/Cable Duct			
	<ul style="list-style-type: none"> - Supply 	<ul style="list-style-type: none"> - Purchase from manufacturers with metallic sheathings coated with water soluble rust-preventive oil. 	<ul style="list-style-type: none"> - Same as Q-2. 	<ul style="list-style-type: none"> - As in Q-3, but preferable to fabricate sheathing freshly at site at the required rate.
	<ul style="list-style-type: none"> - Workability and Transverse bending test as per IRC:18 	<ul style="list-style-type: none"> - Test certificate by the Manufacturer for each lot to be furnished. 	<ul style="list-style-type: none"> - As in Q-2, but additional independent test to be done on random samples. 	<ul style="list-style-type: none"> - As in Q-3, but at higher frequency plus any additional test that QA team may require.
5.8	Any other materials (like expansion joints, bearings, railing etc.)	<ul style="list-style-type: none"> - Manufacturers' Certificate supported by sample testing. 	<ul style="list-style-type: none"> - As in Q-2 with higher frequency of testing and - QA plan of manufacturer to be initially approved. 	<ul style="list-style-type: none"> - As in Q-3 with implementation of QA plan of manufacturer to be audited by QA team of owner to the extent depending on the importance of the item.
5.9	New Materials	<ul style="list-style-type: none"> - Normally not to be used. If used, same as Q-3. 	<ul style="list-style-type: none"> - To be accepted by competent technical authority for use after full testing at laboratory/and field trials. 	<ul style="list-style-type: none"> - As in Q-3 supplemented by independent checking by QA team of specialist consultants.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
6.	WORKMANSHIP		<ul style="list-style-type: none"> - Special specifications for properties, testing and acceptance criteria to be evolved and laid down for use at site. 	
6.1	General Controls : (Direct & Indirect)			
	a) Working & Supervision	<ul style="list-style-type: none"> - Skilled and semi-skilled workers. - Periodic supervision from owner or his agent. - Periodic check by designer during site visit. 	<ul style="list-style-type: none"> - Skilled workers having special training and working under experienced supervisors. (Where trade qualifications are existing should be insisted upon). - Full time supervision from contractor as well as from owner or his agent. - As in Q-2, but at predetermined stages and frequency. - Documented inspection and certification of compliance by designers' representative. 	<ul style="list-style-type: none"> - Same as Q-3. - As in Q-3 but with occasional supervision by expert external agency. - As in Q-3, except in case of bridges having new technology/ design full-time site representative of design agency will be necessary. - Same as Q-3.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
	b) Use of Mock- ups*	- Not ordinarily required.	- For Q-3 quality mock-ups are required only for certain elements (typical slice and difficult zones), which should be specified in tender document. Mock-ups to be carried out in presence of designer and QA team of owner. - Mock-up should use actual proposed methods of construction, including plant and equipment. - No work on structure should be permitted before demonstrative mock-up.	- As in Q-3, but made mandatory for all difficult and important zones. - Also, mock-ups dealing with new techniques to be carried out under supervision of expert external agency. - As in Q-3.
6.2	Concrete mix design	- Mix design performed at beginning of work or for new source of materials with subsequent Q.C. as per code and by experienced supervisors.	- As in Q-2 with minimum two level controls.	- As in Q-3.

*** Notes :**

Full scale mock-ups of part of structure are made for various purposes as follows :

- 1) Verification of proper detailing and choice of concrete mix and making modification in either or both to achieve satisfactory concreting.
- 2) To establish effective methods of transporting, placing and compacting.
- 3) Training of workers for operation in (2) above.
- 4) To demonstrate efficacy of the overall construction operations in achieving its aim.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
6.3	Fabrication and fixing of reinforcement	<ul style="list-style-type: none"> - Site bending by skilled workers with regular checking by qualified supervisor. - Bar bending schedules are made and checked before use. - Correct placement of reinforcement and provision of proper cover checked independently before concreting. 	<ul style="list-style-type: none"> - Same as Q-2. - Same as Q-2. - As in Q-2, but checked and documented by QA team. 	<ul style="list-style-type: none"> - Same as Q-2. - As in Q-2 except bar bending schedule made by design office only. <p>Same as Q-3.</p>
6.4	Fabrication & Fixing of Prestressing Cables a) Cleaning b) Preparation of steel/cables	<ul style="list-style-type: none"> - Normally not applicable. If used, follow Q-3 practices. 	<ul style="list-style-type: none"> - Should be free of rust. Light rust on wires (not strands) can be removed, wires cleaned and used. - Pre-fabricated and sheathed cable can be permitted. However, post-threaded wires/strands just before stressing are to be preferred. - Cables strictly prepared on raised/clean benches and kept free from dust at all times. 	<ul style="list-style-type: none"> - Only unrusted steel can be used. - Only post threading of wires/strands permitted (with exceptions if unavoidable). - Same as Q-3.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
	c) Laying & Supporting		<ul style="list-style-type: none"> - Cable layout prepared giving co-ordinates at close intervals as needed by fixing requirements (and not by theoretical curves or equations alone), and supported firmly in place. Post threaded cable ducts should be held against floatation during concreting. - Layout and leak tightness of sheathing to be independently checked and documented by owner's Q.A. Team of his agent. 	<ul style="list-style-type: none"> - As in Q-3. - As in Q-3, with additional checking and testing required by QA teams. Sample checking by expert external agency.
6.5	Formwork a) Materials	<ul style="list-style-type: none"> - Any suitable material meeting codal requirements and capable of giving specified form finish. 	<ul style="list-style-type: none"> - Same as Q-2. 	<ul style="list-style-type: none"> - As in Q-2 with regularly and properly maintained shuttering with limited re-uses. Shuttering capable of absorbing air released from concrete and providing good insulation to control thermal gradients is to be used. If steel shutters are used, plywood liners or provision of sack-rubbing after deshuttering.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
	b) Design Check	- Spot checks.	- Formwork/design made and approved independently.	- Same as Q-3.
	c) Specialist Systems	- Specialised formwork systems need not be insisted upon.	- Specialised formwork system, to be preferred with properly trained carpenters/fitters.	- Same as Q-3.
	d) Experienced carpenters/fitters	- Semi-skilled/skilled carpenters/fitters under supervisory staff	- Skilled carpenters/fitters under supervisory staff with the work supervised additionally by owners' supervisors or agents.	- Same as Q-3
	e) Tolerances, geometry and leak-tightness checks	- Frequent checks by carpenters/fitters and checking of important members by supervisory staff.	- Checks for all members by supervisory staff	- As in Q-3. Also check for quality of shutter surfaces before re-use & document clearance.
	f) Deshuttering	- Under supervisory staff for important members.	- As in Q-2. The system should provide for gradual, uniform and shock-free deshuttering arrangements.	- Same as Q-3.
	g) Formwork for Special Structures	- Not Applicable.	- As per design requirement under control of qualified staff, with additional supervision by owners' supervisors or agents. Checks by QA team till procedures at site are established.	- Same as Q-3.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
6.6	Mixing/Conveyan/ Placing/Curing of Concrete	<ul style="list-style-type: none"> - Site mixing by mixers or batching plant near site. Occasional two tier control and documented. - Transportation by head loads/trolleys or by mechanised vehicle permitted - Experienced concreting gangs under supervisory staff. - Placing concrete and compacting under supervisory staff - Proper curing under frequent checks 	<ul style="list-style-type: none"> - As in Q-2 under two level controls, upto 200 m length of bridge beyond which batching plant is mandatory - Use specialised equipment for transportation. The adverse effects of the methods of conveyance (segregation delays stiffening of mix etc.), should be regularly monitored controlled and documented. - As in Q2, with two level controls. Also regular control by qualified staff. Method of control by pour card recommended. - As in Q-2. Also regular control by qualified staff. Surveillance by QA team. - As in Q-2, but checked by independent supervisors and documented. 	<ul style="list-style-type: none"> - Batching plant is mandatory. Occasional checks by expert external agency. - As in Q-3. - Same as Q-3. - Same as Q-3, but occasional check by expert external agency. - Same as Q-3, efficacy of methods to be regularly checked and demonstrated.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
6.7	<p>Stressing of Cables</p> <ul style="list-style-type: none"> - Stressing equipment - Stressing Operations - Check of friction and wobble losses 	<ul style="list-style-type: none"> - Normally not applicable if used, follow Q-3 practices. 	<ul style="list-style-type: none"> - Stressing equipment calibrated, tested and certified by manufacturer / supplier. - Checking and re-calibration at site at regular pre-determined frequency by qualified staff under supervision of owner and his agent. - Only under strict supervision of stressing supervisor and site engineer. The manufacturer to supply special assistance at site to train personnel and supervise work. - Sample basis check for elongation/pull in of all wires/strands in the cable assembly (uniformity of stressing). - In-situ check on losses by stressing from one side jack using as active jack and other as a passive jack on a sample basis. 	<ul style="list-style-type: none"> - As in Q-3, in presence of independent expert or by QA team. - Same as Q-3, with surveillance by expert external agency/ or QA team. - Same as Q-3. - As in Q-3 with additional tests as required by QA team.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
6.8	Grouts & Grouting	<ul style="list-style-type: none"> - Normally not applicable. If used then follow Q-3 practice. 	<ul style="list-style-type: none"> - (For long cables and high total deviation the passive jack may not register pressures within stroke length of active jack. For such cases special tests or provision of short cables may be required.) 	
	a) Grouting of Prestressing Cables		<ul style="list-style-type: none"> - At the beginning of work for designing suitable grouts. 	<ul style="list-style-type: none"> - As in Q-3 which check for every operation.
	<ul style="list-style-type: none"> - Composition and Physical properties 		<ul style="list-style-type: none"> - Physical properties to be verified once in a week or with change of batch of cement or admixture. 	
	<ul style="list-style-type: none"> - Fluidity test, bleeding characteristics during working. 		<ul style="list-style-type: none"> - By visual inspection 	<ul style="list-style-type: none"> - As in Q-3 but tested and documented for every operation.
	<ul style="list-style-type: none"> - Equipment 		<ul style="list-style-type: none"> - Testing at frequency of once a week or with change of batch of cement/admixture. - Equipment tested & passed for satisfactory performance regularly. 	<ul style="list-style-type: none"> - As in Q-3 but tested and documented for every operation. - As in Q-3 with testing witnessed by independent QA team.

Sr. No.	Item	Normal QA Q-2	High QA Q-3	Extra High QA Q-4
	<ul style="list-style-type: none"> - Workers/Super-visors - Admixtures b) Grouting with non-cementitious/special materials c) Cement Grouting for bolts & fixing apparatus 	<ul style="list-style-type: none"> - Use of special pre-packaged high strength non-shrink grouts preferred. Methods to be established on mock-up. 	<ul style="list-style-type: none"> - Trained staff under qualified supervision. - Surveillance by QA team. - Where used, as per item 5.5. - Normally not required. If used follow Q-4. - As in Q-2 with regular sample checks for efficacy. 	<ul style="list-style-type: none"> - Same as Q-3 - As per item 5.5. - Materials like grease, powder coatings, or other specially formulated mixes should be used only after thorough testing for suitability including long term effects and by following specially developed suitable methods under expert supervision. - As in Q-3 with increased frequency of checking.

SECTION 4

TYPICAL QUALITY ASSURANCE PLAN FOR CONSTRUCTION AND DESIGN

4.1. Introduction

Quality Planning to assure quality of product has been adopted over the last few decades for special and complex projects. However, in case of bridge engineering and construction, some efforts in this regard are visible only in the recent few years. As a result of continuing efforts, it has become possible to evolve appropriate methods and level of documentation for Quality Assurance Plan for bridge projects.

Surveillance of project implementation if well organised into a quality assurance plan, contributes towards the quality. For this, step by step procedures, which would help in achieving consistent and comprehensive methods of checking and approval of works at every stage, need to be established and documented. These procedures should be reviewed periodically, amended as found necessary, and revised documents prepared.

All parties involved in the QA plan should have their internal QA systems clearly defined in form of a specific Quality Assurance Manual (QAM) for the respective purposes, such as, QAM for Design (by the Design Organisation), QAM for construction (by the contractor), QAM for manufactured products (by the manufactures or suppliers). It is also necessary for owner/purchaser to have his own internal QA plan. QAM for bridge projects as a whole integrating all these plans shall be prepared/or approved by the owner and/or approving authority, if any. Each vendor (i.e. supplier, designer, contractor, manufacturer) will thus have its own internal QA procedures which are required to be agreed upon, in advance, with the purchaser of the respective activity. As bridge building in India is mostly undertaken by Govt. agencies, it is necessary that the contractor/designer obtains concurrence of their QAM from the concerned Government Department ('Department'). The Guidelines provided in Sections 2 and 3 should be used by the respective parties in evolving their internal QA Systems. As an illustrative example, this Section 4 deals with the structure and contents of the operational QAM to be agreed between the contractor and the Department for adoption at site.

Quality assurance plan for a bridge construction project, documented in quality assurance manual, would essentially comprise the following aspects :

- Organisation
- Control of data and documentation, both product (bridge) related documents, and quality related records together with control documents
- Q.A. procedure for setting out of works and temporary works
- Methodology of working
- Control of materials
- Control of workmanship aspects
- Protection during construction stage
- Non-conforming products
- Quality audit

4.2. Organisation

In most of the cases, the management of the constructor shall be responsible for jointly reviewing the requirements of the project with the owner, and structuring the appropriate organisation for the same. This project specific organisation is headed by Project Engineer. The duties, among the staff below him could be generally on the following functional lines :

a) Planning Engineer

Covering all aspects of work planning, resource requirements of both materials and labour, progress review and internal interface activities.

b) **Materials Engineer**

In-charge of material management including procurement and quality control aspects viz. inspection, field sampling and testing.

c) **Construction Engineers (No. as per requirement)**

In-charge of various construction activities and responsible for following approved working methods, drawings and specifications.

d) **Plant, Equipment and Instrumentation Engineer**

In-charge of deployment, operation, maintenance of various mechanical and electrical plant and equipment, as well as instrumentation needed at site for construction.

e) **Other Aspects as required**

This includes responsibilities for safety, human resources etc.

f) **Quality Assurance Engineer**

Responsible for all aspects of preparation, review, acceptance of quality plan and operation of the same at site. He is also in-charge of quality related records and documents.

g) **Quality Audit**

Independent team reporting to management.

The duties of assisting engineers and supervisory staff at various levels should be clearly specified as are relevant to the quality assurance systems. Depending on the specific project requirements and size, the number of staff doing various functions listed above can be increased/decreased.

(Note : The organisational designations of persons performing above tasks will depend upon the constructors' organisations).

4.3. **Control of Data and Documentation**4.3.1. **Bridge Related Documents**

Drawings, specifications, work instructions and other bridge related documents shall be maintained as described below to ensure that only the latest approved documents are used for the construction of each part of the work, which covers both the temporary and the permanent works :

- a) The issuing authority should maintain the registers of drawings/documents giving information about reference number, revision reference, title, date of issue, to whom issued, number of copies issued, status of issue, date of approval, purpose of issue etc. (Superseded drawings/documents shall be so superscribed boldly across the heading block).
- b) Receiving officer to whom documents are issued at site should maintain similar record.
- c) Maintenance and accessibility of site instructions book/order book with both issuing party and to whom issued.
- d) Maintenance and accessibility of registers of correspondence files.
- e) Daily diary of work.
- f) List of Registers on site.

4.3.2. **Quality Related Records and Documents**

For quality assurance of work, it is essential to document each and every operation and activity connected with the work and maintain the record of inspections, approvals/non-approvals and other statistical day to day information about the progress of work. These are normally recorded in the standard forms (to be specially evolved for each activity) and they constitute an important component of the Quality Assurance Manual. Each activity or operation could be broadly categorised as under :

a) **Method Statement**

The method statements give detailed proposals of the constructing agency which are approved by the 'Engineer' (owner's Engineer in-charge of the project). These method statements are written in form of various steps in a particular sequence supplemented by suitable sketches to be self-explanatory. No change shall be carried out from the procedures prescribed in the method statements without first obtaining approvals to such changes from the 'Engineer'.

b) **Inspection Proforma**

These are used for the purpose of seeking approvals from the 'Engineer' or his representative before commencing every operation, such as, pour cards for concrete, approval to reinforcement, approval to formwork, approval to setting out, approval to prestressing, approval to grouting, etc. These are usually supplemented by standard checklist which have to be verified by the 'Engineer' and after he is satisfied about the various points, the approval is then accorded on that form.

c) **Test Results**

This set of proformae is meant for recording the results of day-to-day tests carried out in accordance with the requirements or specifications. The proformae are usually maintained in two forms; one is loose leaf system for recording the various observations during each test and second is for recording the summary of test results in a register form to facilitate later analysis.

d) **Daily Diary of Work and Quantity Records**

Elaborate registers are required to be maintained at site to record the day-to-day operations, activities and events taking place at the site of work such as equipment deployed, manpower deployed, activities carried out, different types of materials consumed, detailed observations of the activities at site (foundation strata, tilts, shifts, etc.), stressing, grouting, visits by senior level engineers and follow-up of their instructions. These records will enable preparation of the completion report as well as investigating any unusual observations which come to notice afterwards.

e) **Non-conforming Products**

Detailed statements have to be prepared describing the procedures to be followed as soon as any result not conforming to the requirements (or unusually better results) is obtained. Such statements deal with the (i) procedures to be adopted for rectification of the particular component where such result has been noticed, (ii) the long term corrective action, and (iii) immediate preventive actions in other similarly affected activities till the long term corrective actions are implemented.

f) **Quality Audit**

A separate set of proformae with detailed instructions are laid down for facilitating the audit of the quality assurance by an independent unit at periodical intervals.

4.4. **QA Procedure for Setting Out Works and Temporary Works**

A professional qualified surveyor shall be appointed to take responsibility of survey control and setting out both the temporary as well as the permanent works and establishing and maintenance of control station following approved work methods. Proper quality records shall be maintained. Under this item, the various elements to be covered should include :

- Survey control stations
- Setting out points
- Schedule of stations and points
- Control and checking of stations
- Approval of stations and setting out

Temporary Works

Construction of temporary works shall be the responsibility and liability of the contractor. The work shall be done with the approval of the 'Engineer'.

The design of the temporary works should also be got approved by the contractor from the 'Engineer'. Temporary works are generally as under :

- a) Centering and formwork
- b) Hoists for material transportation
- c) Temporary lifts during construction
- d) Scaffolding for plastering etc.

The procedure for maintaining records of temporary works shall include :

- Design, drawings, method statement, etc.
- Checking and approval of proposal of temporary works,
- Erection procedures,
- Checking and approval of erection,
- Certification by competent authority,
- Monitoring during loading and use,
- Dismantling the temporary works.

The above items should be checked by the appropriate authorities from the 'Engineer'.

4.5. **Methodology of Working**

Method statements for the execution of the permanent work as per the drawings/specifications shall be submitted by the Contractor to the 'Department' for approval. The procedure for this shall generally include:

- Submission of method statements to 'Engineer'
- Checking of the proposal
- Trials of method, if required and assessment of trials
- Sample of the permanent works and its assessment
- Execution of permanent works, and
- Ongoing review of the method

4.6. **Control of Materials**

The main aspects for materials to be covered in the QA Plan are as under :

- Testing of materials for source approval
- Inspection and certification of materials on receipt
- Testing of materials going into construction
- Test Records
- Assessment and Analysis
- Test frequencies and calibration schedule
- Storage and issue of materials
- Inventory.

4.7. **Control of Workmanship Aspects**

To achieve the desired workmanship at various stages of work, it is necessary to carry out inspection in a regular and systematic manner. The Constructor shall devise an appropriate system for such inspections and get it approved from the 'Engineer'. Following points should be considered for inspection of various components/operations:

- Method statements including tolerances
- Request forms for inspection
- Inspection proforma
- Authority levels for inspection
- Inspection procedures (preliminary, periodic and on completion checks)
- Check lists to systematise the inspections
- Record inspection.

The above points should be considered for the various activities involved in construction such as formwork, reinforcement, concreting, prestressing, grouting, finishing, etc.

4.8. **Protection During Construction Stage**

In order to produce a quality end product, it is necessary to lay down procedures for preventing any damage or deterioration of the various materials brought to site as well as the works partially completed or fully completed till the completion of the entire job.

These procedures will have to be laid down in respect of the following :

- a) Storage of materials like cement, rebars, prestressing steel, bearings, expansion joints etc., and their protection till use.
- b) Protection of the partially completed components of the bridge, both from the point of view of structural stability (including the hydraulic factors) and from the adverse effects of the environment. Particular attention needs to be paid to exposed reinforcement, strands etc.
- c) Prevention of accidents to the structure as well as all personnel working on the project due to incomplete work, or works in progress.
- d) Servicing of some of the components particularly in case of projects being carried out over a long period of time such as oiling and greasing of bearings, filling of the joints and expansion joints, etc.

If any deterioration is noticed inspite of protective measures, the same shall be rectified before taking up subsequent operations.

4.9. **Non-Conforming Products**

For quality assurance of the finished work, it is necessary for the materials and workmanship to fully comply with the work requirement. Non-conforming work shall be rejected.

Special situations, however, arise such as strength of concrete where non-conformance may only be known after sometime, e.g. after 28 days. Therefore, separate detailed procedures should be laid out for dealing with such non-conforming concretes, (Refer proforma E-1 for further guidance).

4.10. **Quality Audit**

The Quality Assurance Manager of constructor and 'Department' shall establish documents and programme for an independent quality audit, which shall objectively evaluate the extent of compliance with the quality systems and their effectiveness. The audit shall include the process and product quality audit as well as the assessment of adequacy of systems as laid out in QA Manual.

The audit programme shall assign qualified personnel to perform such audits and define the procedures and frequency of audits, the method of reporting the findings and recommendations and the means for corrective actions and their re-audit.

4.11. **Design Aspects**

It is assumed in the earlier sub-section that the design is not the contractor's responsibility and is separately finalised by the Department. However, where the contractor is also to supply the design, the QAM should include the agreed procedures for the items listed below to achieve QA in design:

a) **Organisation and Functional Responsibilities (Including Personnel Qualifications)**

Responsibilities for ensuring quality by persons in-charge of design, and assuring that the stipulated quality indeed has been achieved (assurance function of QA team) need to be clearly defined.

b) **Design basis report for development of design**

This includes :

- Requirements of project/client
- Preliminary drawings and data: Source, responsibilities of supply and methods of verification
- Design approach, applicable codes, special design specifications
- Methods of analysis, calculation, checking and internal approvals
- Contents of design reports (detailed calculations)
- Final drawings
- Checking and approval by external approving authority, if any.

c) **Preparation and approval of designs**

This includes :

- QA on software (prior testing and verification)
- Design preparation
- Design verification (independent review, alternative analysis and qualification testing)
- Interface control (internal & external)
- Control of manufacturers/vendors design
- Approval to design, distribution of design documents and document control
- Design change requests
- Checking and approval by external approving authority, if any.

d) **Audit and corrective actions**

e) **Design documentation and records**

4.12. **Proformae of Quality Records**

As mentioned earlier, exhaustive and detailed proformae will have to be evolved and prescribed for the above purpose for each of the major bridge to suit its special requirements, which form a part of the Quality Assurance Manual for that bridge. However, certain typical proformae which have been adopted on some of the work sites in India, are attached for each of the category to give an idea of the structure of these forms. These are not complete in themselves and they need to be modified, augmented or supplemented according to the needs of a particular work.

SECTION 5

TYPICAL PROFORMAE

Note:

Typical proformae which have been adopted on some of the work sites in India are attached to give an idea of the structure of these proformae. These are indicative and may be modified, augmented or supplemented according to the needs of a particular work. The proformae are divided into categories :

- Category A: Planning Proformae
- Category B: Inspection Proformae
- Category C: Surveillance Proformae
- Category D: Proformae for Registers and Records
- Category E: Proformae for Procedural Guidelines of QA System

QUALITY PLAN FOR COARSE AND FINE AGGREGATE

Sr. No.	Description Tests/Items	Acceptance Standard	Performance Standard	Performing Agency	Quality Assurance Agency	Frequency of Performance	Frequency of Assurance	Frequency of Audit
1	Prequalification of source	IS 383	IS 2386 and Project Specification	QA/E	QA/E	Before call of tenders and award of work	Submission in the form of report	Once in year
1A	Confirmation of sources	IS 383	IS 2386 and Project Specification	E/C	QA/E	Immediately after award of work and before commencement of concreting	Submission in the form of report	Once in year
2	Procurement	Project Specification	Project Specification	C	QA/E	As per requirement	Well in advance of requirement	Once in year
3	Storage	Project Specification	Project Specification	C	QA/E	Immediately after receipt	As required	Once in year
4	Sampling	Project Specification/ IS 383	Project Specification/ IS 383	E	QA/E	As per IS 383	As per IS 383	Once in year
5	Tests:							
5A	Petrographic Analysis	IS 383 ASTM 295	IS 383 ASTM 295	Authorised TP	QA/E	New source or change in quality	New source or change in quality	Once in year
5B	Alkali reactivity	IS 383 IS SP 23	IS 2386	Authorised TP	QA/E	New source or change in quality	New source or change in quality	Once in year
5C	Chloride & Sulphate	IS 383 IS SP 23	IS 2386 ASTM D1411	Authorised TP	QA/E	New source or change in quality	New source or change in quality	Once in year
5D	Deleterious Material	Project Specification/ IS 2386	Project Specification/ IS 2386	E/C	QA/E	One sample per week	One sample per week	Once in year
5E	Crushing value	Project Specification/ IS 2386	Project Specification/ IS 2386	E/C	QA/E	New source/As per requirement	New Source/As per requirement	Once in year

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Contd..

Sr. No.	Description Tests/Items	Acceptance Standard	Performance Standard	Performing Agency	Quality Assurance Agency	Frequency of Performance	Frequency of Assurance	Frequency of Audit
5F	Abrasion (optional)	Project Specification/ IS 2386	Project Specification/ IS 2386	E/C	QA/E	New source/As per requirement	New Source/As per requirement	Once in year
5G	Impact value	Project Specification/ IS 2386	Project Specification/ IS 2386	E/C	QA/E	New source/As per requirement	New Source/As per requirement	Once in year
5H	Soundness	Project Specification/ IS 2386	Project Specification/ IS 2386	E/C	QA/E	New source/As per requirement	New Source/As per requirement	Once in year
5I	Size and Gradation	Project Specification	IS 2386	E/C	QA/E	Daily	Daily	Once in year
5J	Flakiness/Elongation	Project Specification	IS 2386	E/C	QA/E	One sample per week	One sample per week	Once in year
5Ki	Sp. Gravity and Absorption (Normal Agg.)	Project Specification	IS 2386	E/C	QA/E	One sample per week	New source	Once in year
5Kii	Sp. Gravity and Absorption (Heavy ore)	Project Specification	IS 2386	E/C	QA/E	One sample per ten tonne	New source	Once in year
5L	Density/Moisture content	Project Specification	IS 2386	E/C	QA/E	Daily	Daily	Once in year

*E ENGINEER/OWNER C: CONTRACTOR TP: THIRD PARTY QA: QA UNIT

Record:
Record shall be maintained by QA, who will verify, compile and analyse the data.

Prepared by
(for QA Team)

Signed

Date

Approved by :
(For Engineer)

Signed

Date

QUALITY PLAN FOR MIXING WATER/ICE (CRUSHED)

Sr. No.	Description Tests/Items	Acceptance Standard	Performance Standard	Performing Agency	Quality Assurance Agency	Frequency of Performance	Frequency of Assurance	Frequency of Audit
1	Prequalification	Project Specification/ IS 456 IS SP-23	Project Specification	E	QA/E	New source	New source	Once in year
2	Confirmatory Tests	Project Specification/ IS 456 IS SP-23	Project Specification	E/C	QA/E	Before start of project work	As per requirement	Once in year
3	Sampling	Project Specification	IS 456	E/C	QA/E	New source thrice in a year (change of season)	Thrice in a year (change of season)	Once in year
4	Physical and Chemical Tests	Project Specification	IS 456/ IS (Chemical Analysis)	E/C	QA/E	New source thrice in a year	Thrice in a year	Once in year
5	Storage	Project Specification	Project Specification	E/C	QA/E	Daily	Once in a month	Once in year
6	Cleaning of Storage Tank	Project Specification	Project Specification	E/C	QA/E	Once in a month	Once in a month	Once in year
7	Adequacy of Storage Tank	Project Specification	Project Specification	E/C	QA/E	Before commencement of work	Once in a month	One in year

Record: Record shall be maintained by QA, who will verify, compile and analyse the data

Signed : Signed :

Date : Date :

Prepared by : Approved by
(for QA team) (for Engineer)

QUALITY PLAN FOR CONCRETE ADMIXTURE

Sr. No.	Description Tests/items	Acceptance Standard	Performance Standard	Performing Agency	Quality Assurance Agency	Frequency of Performance	Frequency of Assurance	Frequency of Audit
1	Prequalification and Recommendation	IS 9103/ ASTM C494	IS 9103/ ASTM C494	Agency responsible for procurement	QA/E	Minimum 6 months before commencement of work	Before start of work and when source is changed	Once in year
2	Procurement	Project Specification	Project Specification	-do-	-do-	Before start of concreting	Well in advance	Once in year
3	Storage	-do-	Manufacturer/Project Specification	E/C	-do-	After receipt at site	Once in a month	Once in year
4	Sampling	Project Specification/ IS 9103	Project Specification/ IS 9103	E/C or Jointly	-do-	On arrival of fresh stock/Minimum once in 3 months	New stock or once in 3 months	Once in year
5.0	Tests							
5.1	Chemical Analysis	IS SP23 IS 9103	IS 9103	E	-do-	As per requirement or minimum once in a year	As per requirement	Once in year
5.2	pH	IS SP23 IS 9103	IS 9103	E	-do-	Minimum 1 sample per month.	Minimum 1 sample per month	Once in year
5.3	Performance	ASTM C494	ASTM C494	E	-do-	New source/As & when required	New source/As & when required	Once in year
5.4	Records	Project Specification	Project Specification	E/C	QA/E	Daily	Once in a month	Once in year

Contd.

Storage :

- 1) Admixture shall be stored as per direction of manufacturer in a 10 Ton cylinder horizontal container specially designed to take pressure and to minimise wastage.
 - 2) Admixture shall be agitated once in a day and solids if any shall not be allowed to settle.
 - 3) Monthly statement of consumption of admixture shall be maintained.
 - 4) Total chloride, sulphate content and pH value of admixture when 4 kg. of admixture is added to 160 kgs. of water shall not exceed permissible limits of chloride, sulphate content and pH value of mixing water calculated separate.
-

Signed	:	Signed	:
Date	:	Date	:
Prepared by (for QA team)	:	Approved by (for Engineer)	:

Proforma 'A-4'

TEST FREQUENCY SCHEDULE

Specification: IS: (Relevant)

Specified Material:

Consignment Identification No.	Specified Test	Performance Standard	Performing Agency	QA Agency	Frequency of Performance	Frequency of Assurance	Frequency of Audit
	a) Chemical Properties						
	b) Physical Properties						
	c) Special Requirements (As specified)						

Signed :

Date .

Approved by :
(for Engineer)

Signed :

Date :

Prepared by :
(for QA team)

FORMWORK INSPECTION CHECK LIST

LOCATION

DATED:

 CONTRACTORS' INSPECTION REQUEST NO
 CONTRACTORS' DRG OR SKETCH NO.

YES NO N.A.

1. Formwork design/drawing/sketch approved including de-shuttering arrangements
2. Trial panel approved (if required)
3. Formwork alignment correct
4. Formwork levels correct, including screeds
5. Formwork dimensions correct
6. Formwork member spacing correct
7. Formwork member material quality acceptable
8. Falsework member sizes correct
9. Falsework member spacing correct
10. Falsework member material quality acceptable
11. Gaps between primary & secondary members closed/wedged.
12. Face boarding/Plywood/Metal thickness correct
13. Joints between panels closed (no gaps)
14. Joints between panels flush (no steps/lips)
15. Panel flatness acceptable
16. Gaps between secondary members and face panels closed
17. Tie rod material and sizes correct
18. Tie rod spacing correct
19. Tie rods tight, face cones flush
20. Spacers between shutter surface tightly fitting
21. Box outs, cast-in items, ducts fixed correct, securely.

Contd..

YES NO N.A.

22. Prestressing sheathing & vents, alignments & spacing of supports acceptable
23. Empty sheathing secured against floatation
24. Prestressing anchorage positions & fixing acceptable
25. Chamfers/fillets sizes, straightness, fixing acceptable
26. Formwork clean
27. Formwork release oil material approved.
28. Formwork release oil applied correctly.
29. Construction joint preparation satisfactory
30. Contraction/expansion joint preparation satisfactory
31. Safe access constructed
32. Adequate work space provided for labour, equipment
33. Shutter vibrators (if required) location & fixing arrangements approved

Inspected by: (for Contractor)	Name	Signed	Date
-----------------------------------	------	--------	------

Approved by: (for Department)	Name	Signed	Date
----------------------------------	------	--------	------

REINFORCEMENT INSPECTION CHECKLIST

LOCATION

DATED:

YES NO N.A.

CONTRACTORS INSPECTION REQUEST NO.
REF DRG NO.

1. Working drawing checked and approved
2. Latest revision being used
3. Bar schedules approved
4. Reinforcing steel material approved
5. Bar bending & cutting satisfactory
6. Corrosion treatment of bars, if required, satisfactory
7. Bar sizes correct
8. Bar spacing correct
9. Bar lap lengths correct
10. Bar laps at correct locations
11. Bar tied as specified
12. Bar assembly rigid and adequately supported (including spacers/chair supports).
13. Cover to bottom bars correct
14. Cover to side bars correct
15. Cover to top bars correct
16. Cover blocks approved including fixing

Inspected by:
(for Contractor)

Name

Signed

Date

Approved by:
(for Department)

Name

Signed

Date

INSPECTION CHECK LIST BEFORE APPROVAL TO CONCRETE

LOCATION:

DATED:

CONTRACTORS' INSPECTION REQUEST NO.

YES/NO CHECK
OR N.A. INITIAL

1. Method statement approved
2. Batching plant mixers in working order (separate dispenser for admixture, if required, available)
3. Standby batcher in working order
4. Water, sand, coarse aggregate, cement, admixture approved.
5. Water, sand, coarse aggregate, admixture, cement stock sufficient.
6. Concrete conveying arrangement (including transit mixers) available in working condition and of sufficient capacity
7. Formwork approved
8. Reinforcement approved
9. Prestressing sheathing approved
10. Concreting equipment in working order
11. Standby crane, vibrators present
12. Tremie in working order (for under water work)
13. Concrete gang present, including carpenter, steel fixer, mechanics and electricians
14. Access provided
15. Safety arrangements adequate
16. Lighting provided
17. Communications between various points provided
18. Arrangements for arranging suspension/ stoppage of concrete provided

Contd..

**YES/NO CHECK
OR N.A. INITIAL**

19. Curing arrangements made

20. Laboratory notified

Inspected by:
(for Contractor)

Name

Signed

Date

Approved by:
(for Department)

Name

Signed

Date

PROFORMA FOR CONCRETE DELIVERY AND POUR RECORD**1. CONCRETE BATCHING DELIVERY TICKET NO.**

Location of Pour	:	Date	:
Concrete Grade	:	Mix. Temp.	:
W/C Ratio	:	Slump	:
Cement Contents	:	No. of Cubes Taken	:
Max. Aggregate size	:		
Admixutre (Type & Dosage)	:		
Batching Started, Hrs.	:	Batching Finished, Hrs.	:
Quantity Batched, Cu.m.	:	Truck No.	:

2. TRUCK ARRIVED ON SITE :

	Hrs.
Slump Test Result (S)	mm at Hrs.
Discharge Started	Hrs.
Placement Completed :	Hrs.
No. of Sitecubes Taken :	Hrs.
Place Where Cubes Taken	
Placement Temperature of Concrete :	
Ambient Temp. :	
Weather Condition :	

Inspected by:
(for Contractor)

Name

Signed

Date

Approved by:
(for Department)

Name

Signed

Date

POST CONCRETING INSPECTION

Note : Post concreting inspection shall be carried at various stages such as after stripping of side shuttering, each stage of prestressing, decentering and/or as per designers stipulation.

Location :

Date of pour :

Stage of Inspection :

Date of Inspection :

Specified Class

		S or NS*	
Observation		Type of Remark S or NS*	
1.	Position/Dimensions : of the member	Alignment	S or NS
		Levels	S or NS
		Dimensions	S or NS
2.	Surface Defects : (honey combing/ sand streaks/air bubbles/cold joints)	No defects Minor defects Major defects	(Note type and extent of defect)
3.	Class of Finish :	S or NS	
4.	Cracks :	No cracks	
		Cracks	Date first observed :
		Nature of cracks :	
5.	Any other Defect :		
6.	Non conformance report no. :	Report No./ Not Applicable	

Remarks :

In case of NS report in item (1) to (5), it should be examined by competent authority before approval or non approval. If required, a separate non-conformance report (including sketches, photographs etc.) shall be prepared for further action.

*S = Satisfactory, NS = Not satisfactory

Inspected by: (for Contractor)	Name	Signed	Date
Inspected by: (for Department)	Name	Signed	Date
Approval/Non-Approval by: (for Department)	Name	Signed	Date

MATERIAL QUALITY SURVEILLANCE FORM

CONTRACTOR			CONTRACT NO.	
MANUFACTURER	SUPPLIER	SOURCE	PURCHASE ORDER	INSPECTING AGENCY
INSPECTED AT	INSPECTION CERTIFICATE	DELIVERY CHALLAN	DISTIN-GUISHING MARK	DATE OF MFR./ SUPPLY
SHIPPING, STORAGE & OTHER REMARKS		(Satisfactory/ No Satisfactory)		

TEST RECORD

S.No.	Test	Method of Test	Acceptance Limits & Units	Obtained Value	Remarks
-------	------	----------------	---------------------------	----------------	---------

(Appropriate Tests)

Remarks :

Inspected by: (for QA Team)	Name	Signed	Date
--------------------------------	------	--------	------

In Presence of : (for Contractor)	Name	Signed	Date
--------------------------------------	------	--------	------

PRODUCTS QUALITY SURVEILLANCE FORM

NAME OF PRODUCT :

Contractor

Contract to

Manufacturer/Supplier/Source

Purchase Order

Inspecting Agency

Inspection Certificate

Delivery
ChallanDistinguishing
MarkDate of
Manufacture/Supply

Drawing Nos.

Tender Specification Clause

Shipping, Storage & Other Remarks

S. No.	Test	Method of Test	Acceptance Range	Obtained Value	Remarks

Inspected by:
(for QA Team)

Name

Signed

Date

In Presence of:
(for Contractor)

Name

Signed

Date

SURVEILLANCE FORM FOR PRE-CONCRETING OPERATIONS

CONTRACTOR	CONTRACT NO.
ELEMENTS OF STRUCTURE	IDENTIFICATION NO.
	LOCATION

SURVEILLANCE OBSERVATIONS

	WORK DESCRIPTION
1.	Line, Level and Dimension as per Drg.
2.	Availability of adequate approved material
3.	Placing of Reinforcement (Including supports/spacers etc.)
4.	Form works and Scaffolding as per Drawing
5.	Box outs/embedded parts, if any
6.	Cleaning of forms
7.	Arrangements of Plant and Equipment
8.	Walkway for Pouring and Inspections
9.	Safety Arrangements
10.	Curing Arrangement

Inspected by: (for QA Team)	Name	Signed	Date
In Presence of: (for Contractor)	Name	Signed	Date

QUALITY SURVEILLANCE FORM WORKMANSHIP OF CONCRETE

CONTRACTOR	CONTRACT NO.
ELEMENTS OF STRUCTURE	IDENTIFICATION NO.
	LOCATION

SURVEILLANCE OBSERVATIONS

The following items should be observed during concrete pour by the QA Surveillance Team.

1) **Mixing of Concrete**

- Check the concrete class and the respective mix design already approved.
- Check the condition of the aggregates to be used.
- Check the weighing and water dispensing methods adopted during the mixing.
- Check that the mixer machine has been cleaned properly.
- Check that the required mixing time is allowed.

2) **Transportation/Conveyance** (as Specified, but generally to cover following):

- Check if the equipment is in proper working order.
- Check if the specified methods are being followed.
- Check if the stipulated time limits are observed.
- Check if the non-conforming wet concrete is being rejected and disposed off.

3) **Placing of Concrete**

Check that :

- The concrete is not segregated during pour. The height of dropping is controlled.
- The concrete is poured in layers.
- The vibrators are being applied systematically to compact uniformly and adequately, avoiding over vibration.
- The concrete is not being pulled or pushed. Pouring is being done close to the final position.
- The cold joints are not allowed to be developed.
- The under water concrete is being poured only by tremies or pipeline.
- The forms are not getting displaced or deformed during the concrete pour and vibrating.
- No cement slurry is getting lost. Suitable number of carpenters are present to watch and repair formwork during the pour, if required.
- The concrete is poured within the allowable time limits from the time of batching.
- The concrete cubes are taken as required.
- The curing arrangements are satisfactory.

Contd..

- The equipment is in working condition.
 - The equipment is cleaned properly.
 - The quality of wet concrete is as per specifications, (slump, homogenous mix etc.)
 - Continuous supply of concrete is assured.
-

Inspected by:
(for QA Team)

Name

Signed

Date

In Presence of:
(for Contractor)

Name

Signed

Date

PARTICULARS OF WORK

Name of Work _____

Name of Contractor _____

Address of Contractor _____

Contract agreement No. _____

Contract Amount _____

Applicable Schedule of Rates _____

Period of Completion _____

Date of Work Order _____

Stipulated Date of Completion _____

Actual Date of Starting of Work _____

Extensions _____

(1) _____

(2) _____

INCUMBANCY

Sr. No.	Designation*	Name	Period	
			From	To

* Departmental officers' designations covering all officers having execution responsibilities for the project.

REGISTER OF DRAWINGS

Name of Work :
Name of Contractor :

1. Receipt of Drawings

Sr. No.	Drawing No./Date	Revision No.	Brief Title	Issued by/ (source)	Date of receipt	No. of copies	Status of Drgs	Further Action	Signature and Date

2. Issue of Drawings

Sr. No.	Drawing No./Date	Revision No.	Brief Title	Sr. No. of Receipt Register	Issued to	No. of copies	Status of Drg.	Drawing supersedes Drg. No. (if any)	Signature

CEMENT REGISTER

1. Weekly Receipt Issue (For week from _____ to _____)

Name of Work :-

Name of Contractor

Closing Balance at the Site of Work from

previous week_____ bags.

Date	Quantity Received		Qty. Used Bags/MT	Purpose	Closing balance at the end of day (bags/MT)
	Bags / MT	Source			
Total					

For Contractor

Name :

Signed :

Date :

For Engineer

Name :

Signed :

Date :

CONSUMPTION OF CEMENT ON DIFFERENT ITEMS OF WORKS, (THEORETICAL AND ACTUAL)

Name of Work :
Name of Contractor :

(A) Weekly Record of items of Works		
Sr. No.	Item of Work	Quantity of work done during the week

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(B) Abstract for the Week Ending (Indicate Cement Consumption)

Sr. No.	Item of Work	Quantity of Work done		Rate of Cement per unit (bags/MT)	Cement required to be consumed theoretically (bags/MT)	Actual cement consumed (bags/MT)
		Quantity	Unit			

For Contractor

Name

Signed

Date

For Engineer

Name

Signed

Date

RECORDS OF CALIBRATION OF EQUIPMENT

Name of Work

Name of Contractor

ITEM	DATE CALIBRATED & PERSON CERTIFYING (FOR VENDOR OR CONTRACTOR)	*DATE OF NEXT CALIBRATION	DATE OF INSPECTION & PERSON APPROVING (FOR DEPARTMENT)	RESULT OF INSPECTIONS

* Frequency of calibration for different equipment to be specified in advance.

DAILY PROGRESS REPORT

Name of Work :
 Name of Contractor :

Date	Activity Location	Item of Work	Weather Condition	Special Problems/ Difficulties	Remarks	Signature with Date	
						Recorded	Checked

IRC:SP:47-1998

For Contractor

Name

Signature

date

For Engineer

Name

Signature

date

Proforma 'D-7'

REGISTER OF INSPECTION NOTES

Name of Work :
 Name of Contractor :

No. of Inspection Note	No. and Date under which received	Reviewed by	Signature	No. & Date of compliance submitted	Reviewed by	Signature	Remarks

REGISTER OF OBSERVATIONS MEMOS ISSUED FROM THE QUALITY CONTROL CELL

Name of Work :
Name of Contractor :

Year	Observation Memo No.	No. & Date under which it is received	Reviewed by	Signature	No. and date of compliance submitted	Reviewed by	Signature	Remarks

Proforma 'D-9'

RECORD OF PRESTRESSING WORK

1. Name of Work _____
2. Name of Contractor _____
3. Span length _____
4. Span No. _____
5. Name and No. of component _____
6. Date of casting _____
(indicate average cube strength at 7 days and 28 days as per design)
7. Gauge pressure not to exceed _____

Date of Prestressing	No. of cable/wire or pair of wires	Side				Slip observed in mm	Final Extension in mm
		Gauge reading	Initial Extension in mm	Locking pressure	Slip observed in mm		
1	2	3(i)	3(ii)	3(iii)	3(iv)		3(v)

Gauge reading	Side				Total Final Extension in mm	Calculated extension in mm for an initial pull per cable/wire/pair of wire
	Initial Extension in mm	Locking pressure	Slip observed in mm	Final Extension in mm		
4(i)	4(ii)	4(iii)	4(iv)	4(v)	5	6

Theoretical Extension Required in mm	Losses or gain in extension in mm	Progressive loss or gain of extension in mm	Slip observed, if any, after 10 days	Remarks	Signatures	
					AE	Contractors Representative
7	8	9	10	11	12(i)	12(ii)
						12(iii)

For Contractor

Name

Signed

Date

For Engineer

Name

Signed

Date

GROUTING RECORD

Name of the Work : _____

Name of Contractor : _____ Cable No. _____

Span No. : _____ Date of Grouting _____

Date of Cable Installation : _____

Type of Cement: OPC/IIISOPC : _____

Week & Year of Manufacture : _____

of OPC/IIISOPC : _____

W/C Ratio : _____

Name & Amount of admixture
used, if any :

Temp: _____	Mixing Water _____	Grout _____
Time: _____	Start _____	Finish _____
Equipment: _____	Grout mixer _____	Grout Pump _____
Cable Duct: _____	Diameter _____	Length _____
Volume of grout in litres _____		Regrouting _____
Grouting pressure _____		
Cement consumption: _____		
Theoretical _____		Actual _____

Pre-Grouting Checks :

Free of blockage: Inlet: Yes/No	Outlet : Yes/No
Vents: Yes/No	Cable Duct : Yes/No
Leakage observed: Yes/No	Sealed : Yes/No

If cable duct blocked: Remedial Measures _____

Grouting Observations:

Passage of grout through vents :	Yes/No
Passage of grout through outlet :	Yes/No
Any equipment failure :	_____
Post grouting checks :	_____
Probing by stiffwire :	_____

Remarks : _____

Signatures of officers present
during grouting:

For Contractor:

For Engineer:

Name

Name

Signed

Date

Signed

Date

Proforma 'D-11'

PROFORMA FOR RESULT ANALYSIS (CEMENT)

Name of Work :
Name of Contractor :

Type of Cement:

Grade of Cement:

Sr. No.	Consignment No./date	Sample Ref. No./date	Results of Chemical Test C3A, etc.	Results of Physical Test (Fineness, Strength etc.)	Results of Special Tests, if any
			Provide Separate Column for each Test		
No. of Samples					
Mean					
Standard Deviation					
Range					
Remarks:					

For Contractor

Name

Signed

Date

For Engineer

Name

Signed

Date

PROFORMA FOR RESULT ANALYSIS (CONCRETE)

Concrete Grade :

 Slump Test :
 28 Days' Strength:

Notes: For every grade of concrete, separate analysis proforma should be used. Separate analysis proforma should be used with every change in mix-design.

Sr. No.	Sample Ref. No.	Structured Element	Wet Concrete Properties		Hardened Concrete Properties Strength at Age in Days		
			Temp.	Slump	3 Days	7 Days	28 Days
			Provide Separate column for each test				
No. of Samples							
Mean							
Standard Deviation							
Range							
Comments:							

IRC:SP:47-1998

For Contractor

Name :

Signed :

Date :

For Engineer

Name :

Signed:

Date :

GUIDELINES FOR NON-CONFORMING WORKS

1. GENERAL

In broad terms, for the Quality Assurance of the finished work it is necessary for the materials and workmanship to conform with the Contract requirements. Ideally, non-conforming work shall be rejected.

The Statement above is true in general terms but special difficulties arise in the case of concrete, where the non-conformance may only be known after 28 days cube results become available, in which period work has progressed further. In some of the situations, acceptance after repair/review for adequacy is feasible. Therefore, separate procedures are laid out for some of the non-conforming situations. In case the item does not meet the requirements after such repair/review, the non-conforming item should be rejected.

2. CONCRETE WORKS

The primary means by which Quality Assurance shall be achieved is by the procedures described in relevant material qualification and workmanship method statements. The non-conforming concrete items shall be further reviewed, as given below :

2.1 Non-conformance Other than Strength or Finish

In the event that any requirement other than strength and standard of finish is not met then the following procedure shall be followed:

1. The Contractor shall be notified without delay verbally and in writing by the following means:
 - a) Return of the Request for Inspection Form signed "not approved" with the reasons for rejection stated
 - b) Issue of a Site Instruction or Site Works Order or letter stating the facts and confirming that the works are not approved.
2. Approval to carry out concreting of a similar nature shall be withheld.
3. The Contractor shall be asked for his proposals to rectify the non-compliance which may involve re-submission of materials, new trial mixes, revised method statement.
4. The acceptance or rejection of any unapproved concrete work shall be referred to the Engineer.
5. When satisfied with the measures taken to ensure future compliance the Engineer shall confirm approval to continue concrete for permanent works.

2.2 Non-Conformance with Strength Requirements

1. The Specification for concrete recognises the statistical possibility of cube failures and thus limits of means, standard deviation, minimum values of strength are specified. The rejection criteria is set out in the agreement.
2. In the event of cube failures outside the provision of the Contract then the non-compliance procedures described in the specification shall be followed :
 - a) Approval of concreting of similar works shall be withheld.
 - b) All aspects of concreting shall be reviewed.
 - c) The cause of failure shall be identified and measures taken to remedy the problem.

3. Various repair/rectification procedures for commonly arising/non-conformance, are specified in contract. The contractor shall furnish his exact proposals for rectification under consideration.
4. The fact of non-conformance and the proposed rectification procedure is conveyed to the engineer/design organisation of owner (or design consultant) for review and opinion about :
 - i) Acceptability of measure proposed by the contractor, if any.
 - ii) Further non-destructive testing, if any,
 - iii) Acceptability in case strength is achieved at a later age (e.g. 90 days)
 - iv) Acceptability at the level of strength achieved for the stress levels in concerned members
 - v) Acceptance of repair/rectification/strengthening measures with modifications, if required, or rejection.
5. Rejection in case the item does not pass modified acceptance limits after repairs.

2.3. **Non-Conformance with Finish Requirements**

1. Where the required finish is non attained then the non-conformance procedure for repair/rectification, as described in the Specification shall be followed.
2. In addition the following procedures shall be followed:
 - a) Approval of similar form work shall be withheld.
 - b) All aspects of formwork shall be reviewed.
 - c) The cause of poor finish shall be identified.
3. Revised specifications/instructions to avoid further recurrence of non-conformance shall be issued.

3. **RECORDS**

1. It is mandatory that all instances of work outside the Specification are recorded in writing, and conveyed to the Contractor. This ensures that :
 - a) The Contractor is irrefutably informed.
 - b) A record of non-compliance is built up to give a general guide to the Contractor's performance.
2. The records of repair/rectification, retesting, inspection and acceptance shall be kept as part of 'as-built' documentation.
3. Record of all references to designers for concessions/rectification and approval given by them shall be kept.
4. Record of compliance to the modifications in procedures, testing, etc., if any shall be kept.

QUALITY AUDITS

1. PROGRAMME

The Quality Assurance Manager shall establish, document and implement a programme for audits which shall objectively evaluate the adequacy of the functions, systems and procedures as referenced in the Quality Manual.

The audit programme shall define:

1. The functions, systems and procedures to be audited.
2. Personnel qualified to perform audits.
3. Frequency of audits.
4. Method of reporting findings and recommendations.
5. The means for having corrective actions agreed upon and implemented.

Audit shall include on evaluation of process audit as well as product audit :

1. Quality practices, systems, procedures and instructions.
2. Certification, documents and records.
3. Quality of (intermediate or) end product.

Audit shall be carried out by appropriately trained personnel who are not directly responsible for the area being audited.

Audits shall be performed in accordance with documented audit procedures and/or checklists which identify essential characteristics.

Management responsible for the area audited shall review agree, and correct deficiencies revealed in the documented audited results.

All action taken to correct deficiencies shall be re-audited to verify compliance and a close-out report issued.

2. EXAMPLE OF QUALITY AUDIT REPORT

The scope and depth of the Quality Audits shall be determined by the Quality Assurance Team responsible to the management. The procedure for quality audit of concrete is given below for illustrating the principles.

3. QUALITY AUDIT OF CONCRETE

1. Quality audit has to be done by Quality Control cells and includes review and analysis of test results to compute variations.
2. Quality Assurance Engineer with approval of management can establish an index to assess overall quality of concrete. One such method is shown in Table (E-2)-1 for guidance.
3. The overall analysis and assessment of quality index shall be worked out by Quality Control Cell while doing the quality audit. In addition the Engineer shall work out this index at least once a month and keep a record.
4. The Quality Control Cell should forward periodic remarks and observations to the engineer. The frequency of such remarks may be once in 3 months or so.
5. All actions to correct deficiencies shall be re-audited to verify the compliance and a close-out report issued by the auditors.

TABLE (E-2)-1

TABLE FOR QUALITY GRADING FOR CONCRETE CONSTRUCTION

Sr. No.	Item/Factor	* Factor	SCORE					
			5	4	3	2	1	0
1.	QA/QC System/Service available*	A	5	4	3	2	1	0
2.	Storage of Cement*	A	5	4	3	2	1	0
3.	Type and Storage of aggregates	B	-	-	3	2	1	0
4.	Water used Quality*	A	5	4	3	2	1	0
5.	Use of admixtures	B	-	-	3	2	1	0
6.	Type and use of machinery	B	-	-	3	2	1	0
7.	Training of personnel and* level of awareness	A	5	4	3	2	1	0
8.	Client Supervision QTY + Qlty	B	-	-	3	2	1	0
9.	Workability of Concrete*	A	5	4	3	2	1	0
10.	Control and checks on W/C ratio*	A	5	4	3	2	1	0
11.	Sequence of loading in mixer (for tilting mixers)	B	-	-	3	2	1	0
12.	Transport and placing time lag, tools, equipment, skill*	A	5	4	3	2	1	0
13.	Formwork design Accuracy*	A	5	4	3	2	1	0
14.	Formwork - Water tightness*	A	5	4	3	2	1	0
15.	Formwork - Release agent	B	-	-	3	2	1	0
16.	Formwork - Sequence of release	B	-	-	3	2	1	0
17.	Reinforcement: Type and testing	B	-	-	3	2	1	0
18.	Reinforcement: Storage & Fabrication	B	-	-	3	2	1	0
19.	Reinforcement placing and cover blocks*	A	5	4	3	2	1	0
20.	Reinforcement congestion-detailing*	A	5	4	3	2	1	0
21.	Construction joints type-execution*	A	5	4	3	2	1	0
22.	Finishing of concrete-tools	B	-	-	3	2	1	0
23.	Finishing of concrete material*	A	5	4	3	2	1	0
24.	Curing method*	A	5	4	3	2	1	0
25.	Curing Time	B	-	-	3	2	1	0
26.	Surface blemishes*	A	5	4	3	2	1	0
27.	Dimension and profile of finished concrete	B	-	-	3	2	1	0
28.	Testing of concrete frequency	B	-	-	3	2	1	0
29.	Hot weather concreting precaution*	A	5	4	3	2	1	0
30.	Provision for maintenance of concrete surface	B	-	-	3	2	1	0

* Factors A are graded on a scale of 0 to 5 while Factors B are graded on a scale of 0 to 3 and total score is worked out for a given job on its inspection.

*Factor A-Max. score 80 (16x5) Total: Max. 122
 Factor B-Max. score 42 (14x3)

Acceptable concrete to score Total 80/122
 55 on Factors A and
 25 on Factors B

DEFINITIONS AND TERMINOLOGY

A1.0 General

The terms defined below, when used in the context of Quality Systems, have acquired specific meanings and applications rather than the generic definitions found in dictionaries.

Some of the definitions taken from ISO:8402 of 1994 are given under sub-group A2.0 and A3.0. These terms have been further clarified in these codes by additional notes for which reference may be made to the code itself. The notes printed in bracketed italics in this section are added for clarifying the applicability for bridge construction.

It is also found necessary to define certain other general terms in order to clarify their usage in the quality field. Additional terms have been defined which have special context in bridge engineering industry. These are included under sub-group A2.0.

A2.0 Sub-group of General Terms/Bridge Industry Terms

A2.1 Process

Set of inter-related resources and activities which transform inputs into outputs.

[In context of bridges investigations, project preparation, design and construction are part-processes which contribute to bridge-building.]

A2.2 Product

The result of activities or 'processes' (product may be a tangible product: intangible product, such as knowledge or concepts, a design, directions for use).

Product may include provision of a 'service'.

[In context of bridge, these terms refer to the bridge, its components and related services, as also to intermediate products of part-processes.]

A2.3 Service

Result generated by activities at the interface between supplier and the customer, and by supplier's internal activities to meet the customers' needs.

A2.4 Supplier

Organisation that provides a product to the customer. Includes person/group who has undertaken the responsibility of supplying a product/service to other person/group within its organisation for further use.

[In context of bridges, it usually refers to the Contractor, material supplier, or consultant.]

A2.5 Purchaser/Customer

Recipient of a product. Includes person/organisation who has taken a product/service from the supplier for onward delivery, with or without further processing, to other purchaser/customer, or to owner/end user.

[In context of bridges, it usually refers to the owner or contractor.]

A2.6. Owner

The final authority/utility owning the end product.

[In bridge industry, this may be the governmental department/private party.]

A2.7. End User

The actual user of the facility.

A2.8. End Use/End Product

The final product (service) to be produced (by the organisation concerned with bridge industry in context of this guideline).

A2.9. Responsibility

Used in a general sense, this term indicates the explicitly stated or implied duty of the person/organisation to perform and provide the service or product of required quality.

[It is also used in the contract documents for bridges in a sense of 'legal accountability' with or without pre-determined financial obligations (product liability/service liability as defined in A3.7).]

A3.0. Sub-group of ISO:8402 Terminology**A3.1. Quality**

The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs.

[Needs may include aspects of usability, safety, availability, reliability, maintainability, economics and environment, 'Fitness for use', 'fitness for purpose', 'customer satisfaction' & 'conformation to requirements' represent certain facets of quality.]

A3.2. Grade

Category or rank given to entities having the same functional use, but different requirements of quality.

Thus, grade reflects a planned or recognised difference in requirements for quality.

[An article given rating of high grade as compared to similar articles of lower grade does not necessarily and automatically become of adequate quality for satisfying needs.]

A3.3. Requirements of Quality

Expression of the needs or their translation into a set of quantitatively/qualitatively stated characteristics of an entity.

[These are the specifications of characteristics that a bridge should possess in order to achieve the aims of constructing the bridge.]

A3.4. Dependability

Collective term used to describe the availability, performance and its influencing factors: reliability performance, maintainability performance and maintenance support performance.

A3.5. Conformity/Non-conformity

Fulfillment/non-fulfillment of specified requirements (A3.3.) respectively.

[Generally non-conformity should lead to rejection of item.]

A3.6. Defect

The non-fulfillment of intended usage requirement or reasonable expectation including one concerned with safety.
[In context of bridges, defect does not lead to rejection but to repair leading to conformance or acceptance of lower grade of quality.]

A3.7. Product Liability; Service Liability

A generic term used to describe the onus on a producer or others to make restitution for loss related to personal injury, property damage or other harm caused by a product or service.
[The term 'responsibility' is more commonly used in bridge building to indicate contractual/legal accountability. (Refer 'responsibility' in A2.9).]

A3.8. Qualification Process

Process of demonstrating whether an entity is capable of fulfilling specified requirements.
[e.g. qualification of welding.]

A3.9. Qualified

Status given to an entity when capability of fulfilling specified requirements has been demonstrated.

A3.10. Inspection/Self-inspection

Activities such as measuring, examining, testing, gauging one or more characteristics of a product or service and comparing these with specified requirements to determine conformity, when carried out by performer is called self-inspection.

A3.11. Verification

Confirmation by examination and provision of objective evidence that specified requirements have been fulfilled.

A3.12. Quality Policy

The overall quality intentions and direction of an organisation as regards quality, as formally expressed by top management.

A3.13. Quality Management

That aspect of the overall management function that determines and implements the quality policy.
[Quality management includes strategic planning, allocation of resources and other systematic activities for quality such as quality planning, operations and evaluations.]

A3.14. Quality Planning

Activities that establish the objectives and requirements for quality and for application of quality policy.

It cover product planning, managerial and operational planning and preparation of quality plan.

A3.15. Quality Control

The operational techniques and activities that are used to fulfill requirements for quality.

A3.16. Quality Assurance

All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality.

[For effectiveness, quality assurance usually requires a continuing evaluation of factors that affect the adequacy of the design or specification for intended applications as well as verifications and audits of production, installation and inspection operations. Providing confidence may involve producing evidence. It includes giving assurance to internal as well as external parties.]

A3.17. Quality System

The organisational structure, responsibilities, procedures, processes and resources for implementing quality management.

A3.18. Total Quality Management

Management approach of an organisation centered on quality, based on the participation of all its members and aiming at long-term success through customer satisfaction, and benefits to all members of the organisation and to society.

[TQM as long term aim of improving "Quality" itself.]

A3.19. Management Review

A formal evaluation by top management of the status and adequacy of the quality system in relation to quality policy and new objectives resulting from changing circumstances.

[It may be carried by, or on behalf of customer.]

A3.20. Design Review

A formal, documented, comprehensive and systematic examination of a design to evaluate the design requirements and the capability of the design to meet these requirements and to identify problems and propose solutions.

[The capability of the design encompasses such things as fitness for purpose, feasibility, manufacturability, measurability, performance, reliability, maintainability, safety, environmental aspects, time scale and life cycle cost. Design review by itself is not sufficient to ensure proper design.]

A3.21. Quality Manual

Document stating the quality policy describing the quality system of an organisation.

[This is also referred to as Quality Assurance Manual.]

A3.22. Quality Plan

A document setting out the specific quality practices, resources and sequence of activities relevant to a particular product, service, contract or project.

A3.23. Specification

the document that states the requirements with which the product or service has to conform.

[A specification should refer to or include drawings, patterns or other relevant documents and should also indicate the means and criteria whereby conformity can be checked.]

A3.24. Traceability

The ability to trace the history, application or location of an item or activity, or similar items or activities, by means of recorded identification.

A3.25. Quality Loop; Quality Spiral

Conceptual model of interaction activities that influence the quality of a product or service in the various stages ranging from the identification of needs to the assessment of whether these needs have been satisfied.

A3.26. Quality Surveillance

The continuing monitoring and verification of the status of procedures, methods, conditions, processes, products and services, and analysis of records in relation to stated references to ensure that specified requirements for quality are being met.

A3.27. Quality Audit

A systematic and an independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives.

[This is not to be confused with 'surveillance' or 'inspection' which have the sole purpose of process control or product acceptance. It includes quality 'system audit', 'process quality audit', 'product quality audit' and 'service quality audit'. It can be partial audit covering limited aspects.]

A3.28. Production Permit; Deviation Permit

Written authorisation, prior to production or before provision of a service, to depart from specified requirements for a specified quantity or for a specified time.

A3.29. Concession; Waiver

Written authorisation to use or release a quantity of material, components or stores already produced but which do not conform to the specified requirements.

[This should be for limited quantity or period, and for specific use.]

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